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NEAR FIELD SMALL EARTHQUAKE - LONG PERIOD SPECTRUM

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Preliminary analysis of long-period recordings of five central California earthquakes indicates that the long period end of the observed spectra may be influenced by the recording site; that the spectrum for small earthquakes tends to be somewhat peaked; and that a Q of 100 seems to be appropriate for the area of interest. Work in Nevada has led to selection of a site for a continuation of the near-field experiment. The area selected is north of the Mina area and south of Fairview Peak. Stations there would be expected to record at least one event per year with M $\geq$ 4.

I. INTRODUCTION

The objectives of our work under this contract are the following:

(a) Install and operate three long-period stations near Bear Valley, California, as part of the coordinated near-field, small earthquake program.

(b) Investigate long-period spectra of small earthquakes, in relation to various source parameters.

(c) Investigate the radiation pattern of seismic areas in Nevada.

(d) Operate a seismic telemetry network in Nevada to provide epicentral control for seismic activity.

During this period, members of the Seismological Laboratory completed or published seven reports, and abstracts of these reports are given in Section II. The University of Nevada/University of Washington LP stations obtained 69 recordings of five earthquakes in the magnitude range 3.0-4.6. Preliminary analysis of these events indicates that the long-period end of the observed spectra may be influenced by the recording site; that the spectrum for small earthquakes tends to be somewhat peaked; that a Q of 100 seems to be appropriate for the Bear Valley area; and that we should modify our long-period instruments to obtain a broader frequency response. This analysis is described in Section III. Section IV contains a brief discussion of work in Nevada aimed at selection of an active seismic area that could be used for a move of the near-field cooperative experiment to Nevada. The area selected is north of the Mina and Cedar Mountains seismic zones and south of the Fairview Peak zone. Stations in this area would be expected to record at least one event with $M \geq 4$ per year within 50 km of the station. Long-period sensitivity of the instruments would be enhanced by operating them in mine tunnels, and useful data could be obtained on earthquakes down to magnitudes of about 3.

II. ABSTRACTS OF PUBLICATIONS AND REPORTS FOR THIS PERIOD

Gupta, Indra N. (1973). Dilatancy and premonitory variations of P, S travel times, Bull. Seis. Soc. Am., 63 (3), 1157-1161.

Nur's (1972) explanation of the observed premonitory decrease in the traveltime ratio of shear and compressional waves, ξ, in terms of dilatancy is modified by considering the anisotropic characteristics of dilatant rock in the focal region. The expected change in ξ is influenced by the orientation and type of geologic fault as well as the geometry of source and observation points. The shear wave will in general split into two components traveling with somewhat different velocities.

Gupta, Indra N. (1973). Premonitory variations in S-wave velocity anisotropy before earthquakes in Nevada, Science, 182, 1129-1132.

Application of nonhydrostatic stress to rock induces velocity anisotropy, causing the S wave to split into two components traveling with somewhat different velocities. Large premonitory changes in the extent of S-wave splitting have been observed for two earthquakes in Nevada. Observations of the difference between the two S-wave velocities may provide a simple method for predicting earthquakes.

Koizumi, Carl J., Alan Ryall and Keith F. Priestley (1973). Evidence for a high-velocity lithospheric plate under northern Nevada, Bull. Seis. Soc. Am., 63 (6), 2135-2144.

P-wave residuals at stations of the Nevada seismic network are analyzed for 80 teleseisms distributed over a range of azimuth and epicentral distance. For South American earthquakes (azimuth 120° to 140° from Nevada), teleseismic P arrivals at northern Nevada stations Lovelock, Battle Mountain, and Elko are early by as much as 1.4 sec relative to the Tonopah station to the south. The North Reno station has early arrivals, relative to Tonopah, for Leeward Islands earthquakes, at an azimuth of 100° from the station. Interpretation of these residuals indicates the presence of a high-velocity lithospheric plate, striking northeast and dipping southeast, under northern Nevada. The high-velocity plate is interpreted as a paleosubduction zone.

Priestley, Keith F. (1974). Earth strain observations in the western Great Basin, Univ. Nev. PhD Dissertation, 185 pp.

Since the driving force function for the solid earth tides can be calculated quite accurately, the discrepancies between the observed and predicted tides contain important information concerning earth structure. The two principal tidal components discussed in this study are the M_2 semidiurnal tide at both sites compares favorably with the M_2 theoretical tide. The small discrepancies between the observed and predicted M_2 tide are compared with those expected from the tidal load calculations of Farrell and are found to be in poor agreement. These discrepancies appear to be more closely related to geologic and topographic structure near the strainmeter site. The O_1 diurnal tide is severely distorted in the east-west direction. This is likely due to the effect of the large O_1 ocean-load tide along the Pacific coast of North America acting on the heterogenous crust of the Great

Basin. A comparison of the differences in tidal amplitude and heat flow for several sites in the western United States suggests that tidal amplitudes are low in areas of higher than normal heat flow. The average tidal phase lag for the M_2 tide was calculated and found to be 2.1° ± 0.7°. This implies an effective tidal Q of about 10.

Our strain observations at Round Mountain and Mina indicate that the strain rates in this area of the Great Basin are less than 2×10^{-6} per year. These strain rates are considerably smaller than those observed in the vicinity of the Nevada Test Site, but are in agreement with estimated spreading rates and geodetic measurements in the Great Basin. The general agreement between strainmeter observations at Round Mountain and focal mechanism solutions of nearby microearthquakes, suggest that we are observing strain accumulation in that area. Composite focal mechanism solutions for microearthquakes in the Mina area indicate NW-SE extension. Strain observations in that area also indicate long-term NW-SE extension. The observed strain rates are quite variable; however the long-term strain rate is low, on the order of a few parts in 10^7 per year. The strain rates are highest and most variable during periods of increased seismic activity. The principal axes of the observed strain are quite stable in time, however the sense of the motion is variable. There are periods of primarily NW-SE extension followed by periods of NW-SE contraction. This leads us to believe that strain in this area is partially relieved by microearthquakes, partially relieved by other inelastic processes such as creep, and accumulating at a rate no greater than a few parts in 10^7 per year. Strain variations at the time of local earthquakes are suggestive of the precursor effects proposed by Scholz.

Priestley, Keith F. (1974). Crustal strain measurements in Nevada, Bull. Seis. Soc. Am., in press.

Strain measurements at two sites in central Nevada, Round Mountain and Mina, indicate that in this area of the Basin and Range, strain rates are less than 2×10^{-6} per year. These observations are in agreement with estimated spreading rates and geodetic measurements in the Great Basin. The general agreement between strainmeter observations at Round Mountain and nearby focal mechanism solutions suggests that we are observing strain accumulation in this area. The long-term strain at Mina is more variable, but generally agrees with earthquake focal mechanism solutions. The strain rate, in conjunction with the high seismicity of the Mina area suggest that strain has already accumulated, and is presently being released through inelastic processes.

Richins, William D. (1974). Earthquake swarm near Denio, Nevada, February to April, 1973, Univ. Nev. MS Thesis, 57 pp.

An investigation of historic earthquake activity in northwest Nevada shows that earthquake swarms are typical. Evidence suggests that these swarms are associated with geothermal activity. An earthquake swarm occurred during February, March and April, 1973, 20 kilometers south of Denio on the Nevada/Oregon border. The largest event of the sequence was a magnitude 5.3 shock on 3 March. Fault plane solutions indicate right-lateral oblique-slip motion on a plane striking N11°W and dipping 60°E. This mechanism is very similar to those of the 1954 Fairview Peak and other earthquakes in the western Basin and Range, and is consistent with regional extension in a WNW-ESE direction. During March and April, a

small tripartite array recorded more than 1,500 events of this sequence, and 221 of these were selected for detailed analysis. Epicenters of these events fall in a north-south trending zone, 8 kilometers in length and 2 kilometers wide; focal depths range from 5 1/2 to 8 1/2 kilometers. The b-value for this sequence is 1.00 which is considerably higher than 0.81 found for northwest Nevada as a whole. High b-values have been found in laboratory experiments for heterogeneous materials and for rocks under low to moderate stress.

Ryall, Alan and William U. Savage (1974). S-wave splitting: Key to earthquake prediction?, Bull. Seis. Soc. Am., in press.

This paper presents a detailed analysis of S-wave data for two areas in western Nevada. Some of this data was used by Gupta (1973b, c) as the basis for his claim that large premonitory changes in the extent of stress-induced S-wave splitting are observed for moderate-sized earthquakes in Nevada. Analysis of particle motion for an earthquake sequence near Slate Mountain indicates that changes in S-wave splitting did not occur during that sequence. For the Mina area, comparison of S-wave signatures for 158 events occurring over a three-year period resulted in the identification of numerous events that would be considered anomalous by Gupta's criteria, but these were not followed by larger earthquakes. The present state of knowledge on crustal structure and seismic source parameters in the western Basin and Range province is not sufficient to discriminate between stress-induced velocity anisotropy and the many other factors that contribute to the complexity of S-wave signatures.

III. BEAR VALLEY EXPERIMENT

The University of Nevada's three long-period seismograph stations began operation on 29 March 1973. Each of the stations has a three-component set of Geotech long-period seismometers, gain-ranging amplifiers, and a digital transmission system. Response of the system is shown on Figure 1, and the station locations are listed in Table 1. Signals from the three University of Nevada and three University of Washington stations are recorded in a frequency-shift-key format on analog tape, at a recording facility in Hollister. Processing of the tape recordings is carried out at the University of Washington, to produce digital tapes that are compatible with the University of Nevada's CDC 6400 computer.

During the period covered by this report, usable LP recordings were obtained for five earthquakes, in the distance range 16-126 km. Locations of the five earthquakes are given in Table 2, and computer plots of the data are shown on Figures 2-9. Processing of the data for these plots included removal of most of the noise spikes in the original data, and rotation of coordinates to produce radial and transverse signals from the original north-south and east-west components.

Results of analysis are listed in Table 3. Displacement spectral density estimates $\Omega(\omega)$ of all the earthquake signals, and of the noise preceding the signals, were calculated using the Fast Fourier Transform. For spectral analysis of the signal, a 93-second window (1024 samples) was used, except in those few cases where insufficient data was available. The spectrum of the entire seismogram was calculated. The window used for the noise spectrum was more variable (100 to 1024 points), because of variations in the duration of the noise sample preceding the signal.

The calculation procedure used for both signal and noise was identical. The displacement spectral density estimates were corrected for the instrument response and alsc for the dimensionless quality factor Q. The latter correction was

Table 1. Station Locations.

Name	Agency	Latitude, deg. N	Longitude deg. W
East Hollister (EHC)	UW	36.9167	121.3250
Quien Sabe (QSC)	UW	36.8100	121.1633
Le Grant Mine (LGM)	UW	36.5600	120.8317
Panoche Pass Mine (PPC)	UN	36.6684	120.8921
West Hollister (WHC)	UN	36.8711	121.4342
Mt. Toro (MTC)	UN	36.5357	121.6176

Table 2. Events Analyzed.

Event	Location	Latitude, deg. N	Longitude, deg. W	Depth km	M
A.	Bear Valley	36.5900	121.1933	9.5	4.0
B.	Bear Valley	36.5883	121.1967	5.3	3.0
C.	Morgan Hill	37.1950	121.5750	6.0	4.6
D.	Los Gatos	37.1983	122.0067	17.0	4.5
E.	Quarry EQ.	36.7767	121.5717	4.0	3.5

TABLE 3. RESULTS OF ANALYSIS OF AVAILABLE LONG-PERIOD DATA

A. 6/22/73 Bear Valley. M = 4.0, h = 9.5 km.

No.	Sta.	Dist., km	Az., deg	Component	Amax*	$M_o \times 10^{-22}$, dyne-cm	S/N**
1	EHC	38.1	162	E	2220	2.54	320
2	QSC	24.6	186	N	1920	2.19	230
3	LGM	32.5	276	Z	1020	1.82	90
4				E	1990	2.22	270
5				N	2520	2.95	330
6				R	2110	2.11	250
7				T	2850	3.00	340
8	WHC	37.9	145	Z	4000	9.32	310
9				E	7630	13.85	350
10				N	7170	13.10	310
11				R	6640	12.28	260
12				T	7500	14.82	440
13	MTC	38.5	81	Z	660	0.75	90
14				E	1120	1.14	110
15				N	670	1.07	120
16				R	1090	1.13	110
17				T	700	1.06	120

* Amplitude given in digital counts.

** Ratio of Ω (0) values for signal and noise, calculated in range 0.1-0.3 Hz.

B. 2/7/74 Bear Valley. M = 3.0, h = 5.3 km.

No.	Sta.	Dist., km	Az., deg	Component	Amax	$M_o x 10^{-22}$, dyne-cm	S/N
1	EHC	38.2	163	Z	90	0.144	4.4
2				E	170	0.317	11.0
3				N	90	0.209	5.7
4	QSC	24.8	187	Z	100	0.087	6.5
5				E	250	0.204	11.7
6				N	150	0.120	7.5
7	LGM	32.8	276	Z	120	0.175	6.7
8				E	110	0.166	8.1
9				N	120	0.221	12.5
10	WHC	37.9	146	Z	380	0.728	18.9
11				E	1010	2.015	13.5
12				N	500	1.346	9.5

C. 10/3/73 Morgan Hill. M = 4.6, H = 6.0 km.

No.	Sta.	Dist., km	Az., deg	Component	Amax	$M_o \times 10^{-22}$, dyne-cm	S/N
1	EHC	38.1	324	Z	920	1.06	50
2				E	4080	2.34	53
3	QSC	56.3	320	Z	1000	4.93	170
4				E	2340	2.81	97
5				N	1420	5.35	153
6				R	1480	3.49	106
7				T	2630	4.05	135
8	LGM	96.7	317	Z	1160	4.81	54
9				E	2230	11.53	101
10				N	1150	8.31	99
11				R	1270	8.77	125
12				T	2010	11.05	86
13	PPC	84.4	314	E	1500	6.06	55
14				N	1190	4.51	52
15				R	950	3.92	54
16				T	1670	6.34	54
17	WHC	38.1	341	Z	8300	15.92	280
18				E	21800	25.82	199
19				N	7550	18.13	90
20				R	9910	20.30	118
21				T	22206	24.42	152
22	MTC			Z	400	1.48	23
23				E	700	3.37	32
24				N	760	2.59	30
25				R	790	2.58	30
26				T	850	3.39	32

D. 11/12/73 Los Gatos. M = 4.5, h = 17.0 km.

No.	Sta.	Dist., km	Az., deg	Component	Amax	$M_o \times 10^{-22}$, dyne-cm	S/N
1	EHC	68.2	298	Z	420	1.34	11
2	QSC	86.6	300	E	1320	4.18	64
3				N	420	2.28	45
4				R	1220	3.90	70
5				T	720	2.82	49
6	LGM	126.5	304	Z	300	3.13	13
7				E	560	2.91	12
8				N	430	3.36	21
9				R	440	2.96	16
10				T	510	3.32	15
11	PPC	115.4	301	E	290	3.44	15
12				N	500	3.21	21
13				R	290	3.18	14
14				T	530	3.54	26
15	WHC	62.6	306	E	4660	14.41	16
16				N	2800	10.50	13
17				R	3660	12.55	13
18				T	3020	12.80	19
19	MTC	81.3	335	E	790	2.85	6
20				N	770	3.41	18
21				R	520	2.95	10
22				T	970	3.38	8

E. 2/1/74 Quarry Earthquake. M = 3.4, h = 4.0 km.

No.	Sta.	Dist., km	Az., deg	Component	Amax	$M_o x10^{-22}$, dyne-cm	S/N
1	EHC	26.9	235	Z	340	0.52	3.7
2				E	680	0.75	9.4
3				N	1560	0.76	12.7
4				R	1670	0.82	12.4
5				T	670	0.65	8.2
6	QSC	36.6	264	Z	370	0.41	3.0
7				E	450	0.49	5.6
8				N	510	0.58	8.3
9				R	510	0.59	8.4
10				T	440	0.48	5.5
11	LGM	70.4	290	Z	530	0.81	1.8
12				E	330	0.76	2.8
13				N	410	0.97	3.1
14				R	300	0.76	2.7
15				T	390	0.97	3.1
16	WHC	16.1	230	Z	1120	0.91	5.1
17				E	3050	1.29	5.3
18				N	3900	1.49	5.7
19				R	4500	1.62	6.4
20				T	360	1.20	5.0
21	MTC	27.1	9	Z	660	0.15	0.8
22				E	520	0.21	0.9
23				N	270	0.20	1.0
24				R	520	0.21	0.9
25				T	270	0.21	1.0

made by multiplying the spectrum by the exponential term exp (ω R/2 Qβ), where ω is the circular frequency of the spectral estimate, R is focal distance, Q is the dimensionless specific attenuation, and β is the shear-wave velocity. O'Neil and Healy indicate that Q values of between 35 and 100 may be appropriate for data obtained around Hollister, and we therefore used a constant value of 70 for Q in all of our spectral calculations. This is a value considerably lower than that used by other investigators in source-parameter studies. The value of β used in this analysis was 3.3 km/sec.

Moments were calculated from the long-period asymptote of the spectra. The equation used for this is the following (Brune, 1970):

$$M_o = \frac{\Omega(0)\ 4\ \pi\rho R\beta^2}{2\overline{R}_{\theta\phi}}$$

where $\Omega(0)$, the long-period spectral limit, was taken as the average between 0.1 and 0.3 Hz; R is the focal distance; ρ is the density, taken as 2.7 g/cc; β is the shear-wave velocity, 3.3 km/sec; $\overline{R}_{\theta\phi}$ is the average radiation pattern, taken as 0.6; and the factor of 2 in the denominator is to account for the free surface effect.

Moments are listed in Table 3 for all recordings of the five events. For the three events with $M \geq 4$, moments are in good agreement with the moment/magnitude relationship given by Wyss and Brune (1968); moments for the smaller events are probably too high, due to poor S/N ratio over the frequency range used in this calculation. This is illustrated by Figure 10, which shows EHC-N noise and signal spectra for the M = 3.0 shock in Bear Valley. For this event, stations 35-40 km from the epicenter had positive S/N only for frequencies in the range of about 0.2-2.0 Hz. Because of the high microseismic background in the Bear Valley area, useable LP data can be obtained only for earthquakes with M greater than about 3 1/2.

Spectra for the June 22, 1973, Bear Valley earthquake are shown on Figures 11-27. Spectra for the other four events were distributed at a contractors'

meeting, but are not included with this report. Only the shocks with $M \geq 4$ (Table 3A, C and D) will be discussed here; the smaller events (Table 3B and E) had poor S/N and were not useable. Average characteristics of signal spectra for the three larger events are given below in table form, and described in detail in the following paragraphs.

	Period range, seconds	Frequency range, Hz	Description
(1)	15-25	0.04-0.07	Long-period end of spectrum has slope of approximately ω^{-2}.
(2)	10-15	0.07-0.10	Trough.
(3)	5-9	0.11-0.20	Hump.
(4)	1-5	0.20-1.0	Spectrum essentially flat.
(5)	<1	>1.0	Short-period tail has average slope of approximately ω^{3}.

Long-period slope was estimated by eye from spectral plots like those in Figures 10-27, for all components of the three larger events. Taking the slope as $B = \log \Delta A/\log \Delta f$, where ΔA and Δf are amplitude and frequency ratios over the period range of about 15-25 seconds, we find that the slope appears to be in large part dependent on the recording site. Thus, for earthquakes A, C and D, the average slope values are, respectively, -2.9 ± 2.1, -2.2 ± 2.6 and -2.2 ± 2.5, while average slope values for the individual stations for all events are EHC: -2.7 ± 1.4, QSC: -1.0 ± 1.7, LGM: -0.4 ± 1.8, PPC: -3.5 ± 0.6, WHC: -4.8 ± 1.1, and MTC: -2.7 ± 2.7.

Almost two-thirds of the spectra for these events showed a prominant trough in the 10-15 second period range. The period corresponding to the trough minimum varied somewhat from one recording to another, and it was not possible to relate this parameter to magnitude of the event. However, there was a tendency for the trough to disappear with distance: spectra for 22 of the 29 Z, E and N recordings for distances greater than 85 km had this feature.

For periods in the range 1-9 seconds, average spectra for the three events have a broad peak, which is either flat or decreasing slightly toward higher frequencies. For periods less than 1 second, all of the spectra have a tail which increases with increasing frequency proportional to about ω^3. Preliminary analysis of this part of the spectrum indicates that the value of $Q = 70$ used in this analysis is too low, and that the instrument response shown on Figure 1 may be incorrect for frequencies above 1 Hz. The data indicate that Q must have a value of 100 or more, for propagation paths appropriate to our stations and the observed earthquakes.

As shown by Figures 10-27, the noise spectra show a prominent peak in the storm-microseism period range, 5-8 seconds, and spectral amplitudes decrease with a slope of about ω^{-2} for periods of 1-5 seconds. For the 1-4 Hz frequency range, the spectra have a positive slope proportional on the average to ω^4. This is approximately equal to the slope introduced by corrections for Q and the instrument response, and can be explained by a lack of microseismic noise on our recordings for frequencies higher than 1 Hz. The average microseism level is essentially zero for frequencies higher than the peak microseism frequency. Electronic noise in the system leads to a variation of about $\pm$ one digital count and probably accounts for a flat spectrum beyond 1 Hz.

<u>Need for modification in instrumentation</u>. In our original proposal to participate in the Near Field experiment, we planned to telemeter long-period signals via standard VCO's, at two gain levels, to a central recording facility. Later this plan was changed so that our equipment would be the same as the digital recording system designed by the University of Washington. As the results obtained to date illustrate, the digital system is not able to see corner frequencies or high-frequency slope for small-to-moderate sized earthquakes. The reason for this is that the digital transmission system limits our sampling rate to 11 samples per second, per instrument. The instrument was designed to sacrifice some frequency

range for very large (>100 dB) dynamic range; information on high-frequency spectral characteristics was to be supplied by agencies operating accelerometers.

The drawback to this concept is that the accelerometers do not record all the events that are recorded by the LP stations. In addition, station site effects have turned out to be significant, so there is some question about combining the data from different sites. To overcome these problems, we have concluded that the instrumentation should be changed to broaden the frequency response. To do this, we propose to go back to the concept of analog recording with two overlapping VCO ranges per channel. This would limit the total dynamic range to about 70 dB, which should be adequate for Bear Valley earthquakes in the magnitude range 3-5. All of the events recorded so far by the LP array could have been recorded by a system having a 40 dB range.

IV. NEVADA STUDIES

As part of its work under this contract, the University of Nevada operates a seismic telemetry network in Nevada to provide epicentral control for seismic activity, and investigates the radiation pattern of earthquakes in Nevada. A number of reports on various aspects of the Nevada seismicity study are in preparation and will be submitted for publication; work by Gupta, Ryall and Savage on S-wave velocity changes related to stress changes had been published or accepted for publication, and the abstracts are given above in section II. For the purposes of this report, we shall describe work aimed at the selection of a site to which the Bear Valley experiment might be moved in the future.

We are currently operating more than 40 seismographic stations in Nevada, and analysis of the Nevada network data is almost complete through 1973. For the period 1970-1972, epicenter locations and magnitude determinations are complete down to about M = 2 1/2, and 1,200 epicenters for this period are shown on Figure 28. Figures 29 and 30, respectively, show division of the region into seismic zones and recurrence curves for those zones; various parameters for those

zones are listed in Table 4.

In terms of recurrence rates for moderate earthquakes (Table 4), the Fairview Peak and Mina areas are the most active seismic zones in the western Great Basin. In these areas, the return period for a magnitude 5.0 shock within 30 km of a given site is 20-30 years, and the return period for a magnitude 4.0 event within 30 km is 2-3 years. A group of LP stations north of the Mina and Cedar Mountains zones and south of Fairview Peak would be within 50 km of the earthquake sources in all of these areas. Such a group of stations would be expected to record at least one event per year with magnitude equal to or greater than 4.0.

From the standpoint of studying long-period spectral characterisitics of small earthquakes, Nevada would be an ideal region in which to conduct an extension of the Bear Valley experiment. In the area just described, LP instruments could be installed in dry mine tunnels, on hard rock. This would eliminate a problem of surface tilting due to rainfall and temperature changes which has been bothersome in the Bear Valley area, and should permit operation of the seismometers at their maximum period of 30 seconds. In addition, due to the distance of western Nevada from the coast, we should be able to operate LP instruments at somewhat higher gain in this region, and would expect to obtain useful data on earthquakes with $M \geq 3$ in the Mina-Fairview Peak area.

As backup for a move of the experiment to Nevada, the University now operates a dense network of 22 stations in the Mina-Fairview Peak area, in a cooperative program with the U. S. Geological Survey (Figure 31). This network will be expanded to about 35 stations by the end of 1974, and will be capable of providing excellent control on epicenters, focal depths and mechanisms of earthquakes that might be of interest to the Near Field program.

Table 4. Recurrence rates for various earthquake samples in the Nevada region. A -- area of the region considered; $N_{2.0}$ -- number of shocks with $M \geq 2.0$ during 1970-1972; b -- slope of the recurrence curve; T(7.2/100) -- return period for an earthquake with $M \geq 7.2$ within 100 km of an average site; T(5.0/30) -- same with $M \geq 5.0$ and $r = 30$ km; M(30/30) -- magnitude of the event to be expected once every 30 years, on the average, within $r = 30$ km.

Region	$N_{2.0}$	A, km^2	b	T(7.2/100), yrs	T(5.0/30), yrs	M(30/30)
Western Nevada	980	140,000	.85	360	54	4.7
Northwest Nevada	140	143,000	.81	1,490	279	3.8
Fairview Peak	210	2,120	1.11	563	23	5.1
Mina	160	7,910	.93	321	32	5.0
N. Owens Valley	130	14,840	.84	251	40	4.9
Dixie Valley	39	1,690	.97	459	37	4.9
Cedar Mts.	60	3,730	1.18	8,273	233	4.2
Mohawk Valley	111	24,000	.91	1,102	122	4.3

FIGURE CAPTIONS

Figure 1. Response of the University of Washington/University of Nevada long-period systems.

Figures 2-9. Digital plots of LP data for the five earthquakes listed in Table 3. Station codes are followed by component: Z -- vertical; E -- east-west; N -- north-south; R -- radial; T -- transverse. Up on the trace is ground up, east north, toward the source and clockwise, except that the following are reversed: EHCN, EHCE, QSCN, QSCE, QSCZ, WHCE, MTCE. Station codes are followed by scale factors, which indicate the number of digital counts per division on the amplitude scale shown to the left of each set of traces. The time scale is given at the bottom of each figure.

Figure 10. Spectrum to illustrate poor signal-to-noise characteristics for an earthquake with M = 3.0. Light line is noise spectrum, heavy line is signal spectrum. H -- focal depth, in km; D -- hypocentral distance, in km; AZ -- station-to-epicenter azimuth, in degrees NE.

Figures 11-27. Spectra for all recordings of 22 June 1973 Bear Valley earthquake.

Figure 28. Map of Nevada earthquakes for 1970-1972.

Figure 29. Main seismic zones in Nevada, used in estimating recurrence rates.

Figure 30. Recurrence curves for zones shown on Figure 29, for 1970-1972 data. (a) -- Fairview Peak; (b) -- Mina; (c) -- Northern Owens Valley; (d) -- Dixie Valley; (e) -- Cedar Mountains; (f) -- Mohawk Valley.

Figure 31. The University of Nevada/U. S. Geological Survey dense seismic network in the Mina area. This network also includes four stations in the Fairview Peak area to the north, and will be expanded to fill in the area between Mina and Fairview Peak. Closed circles -- operating stations; open circles -- planned stations.

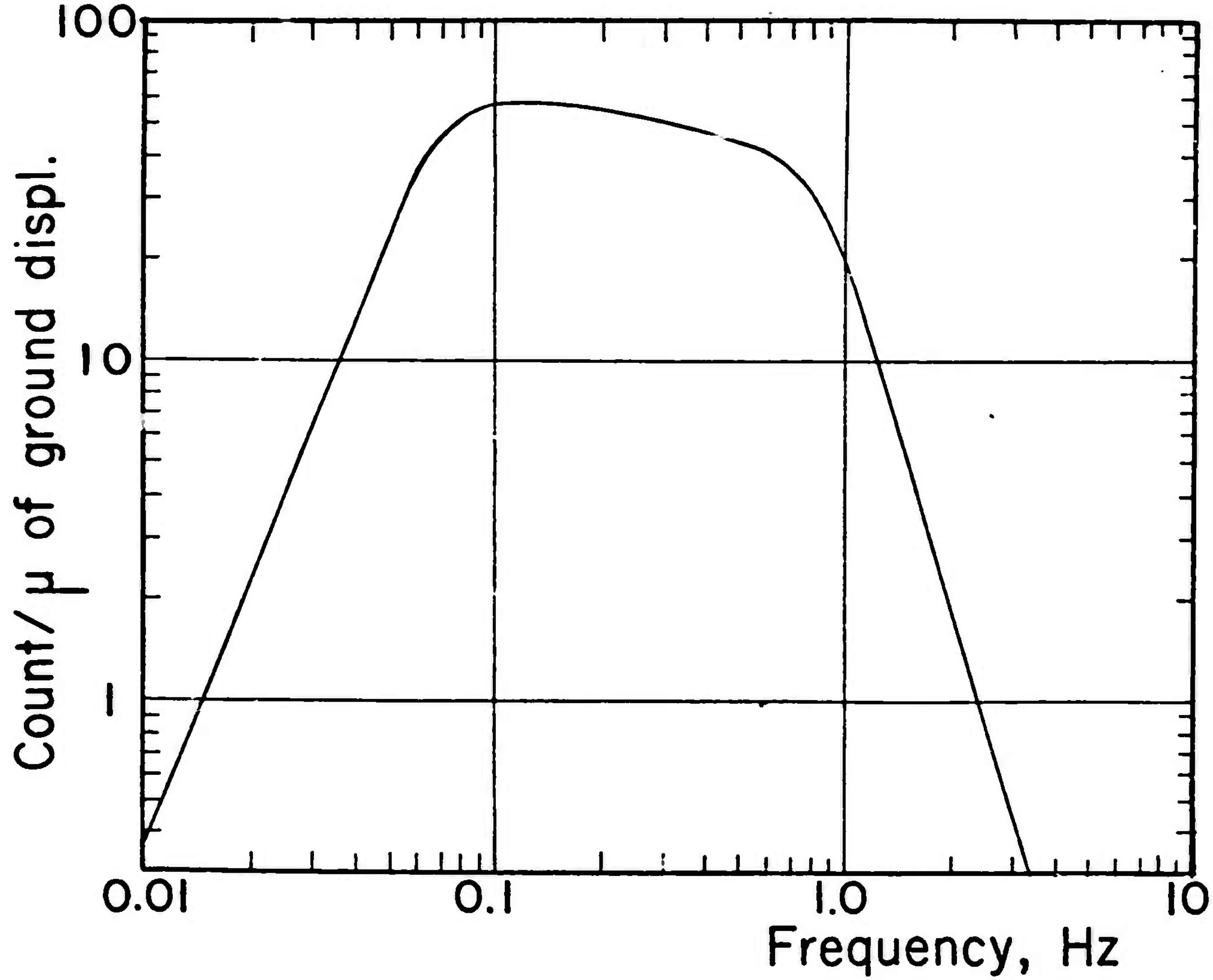


FIGURE 1

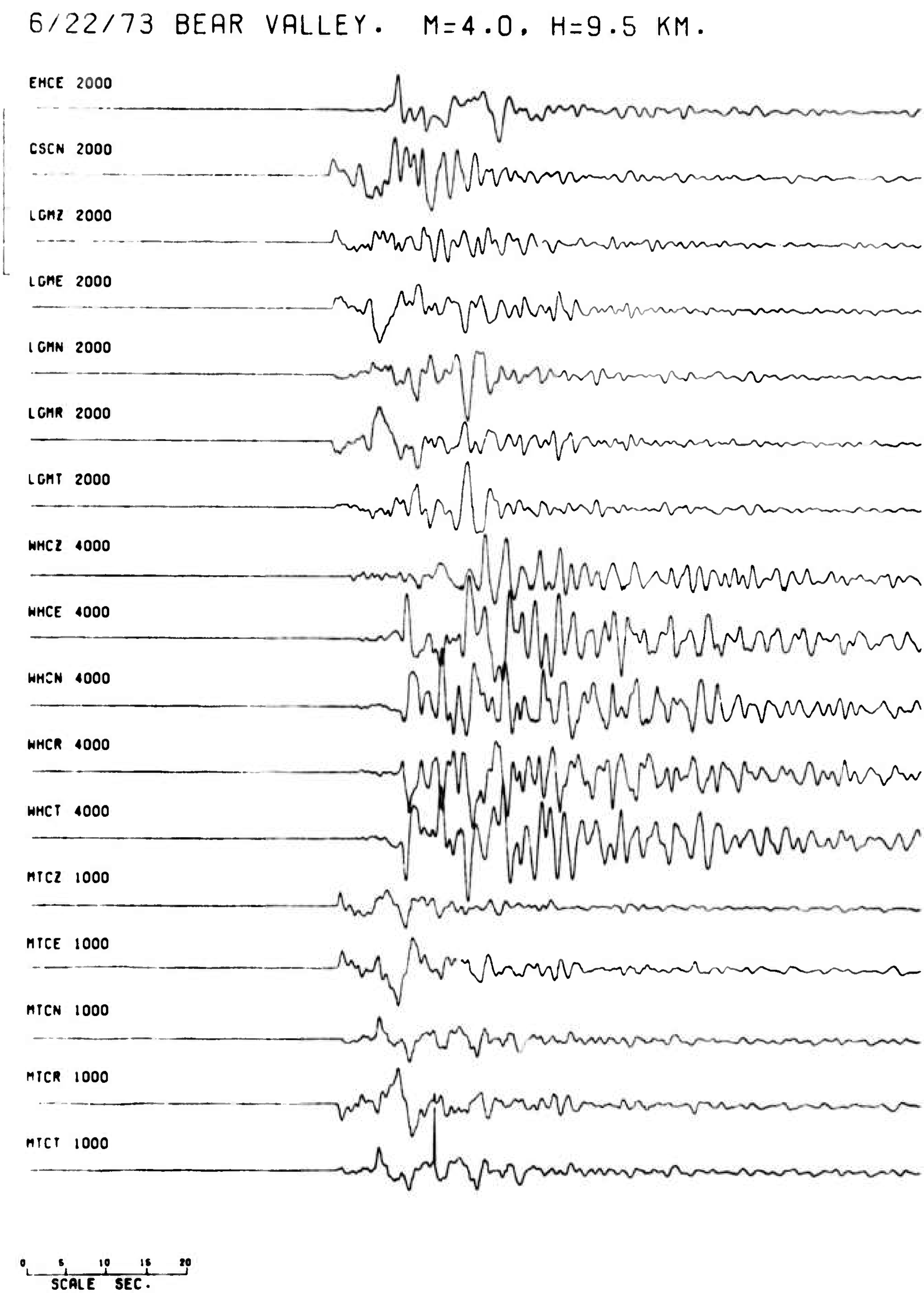
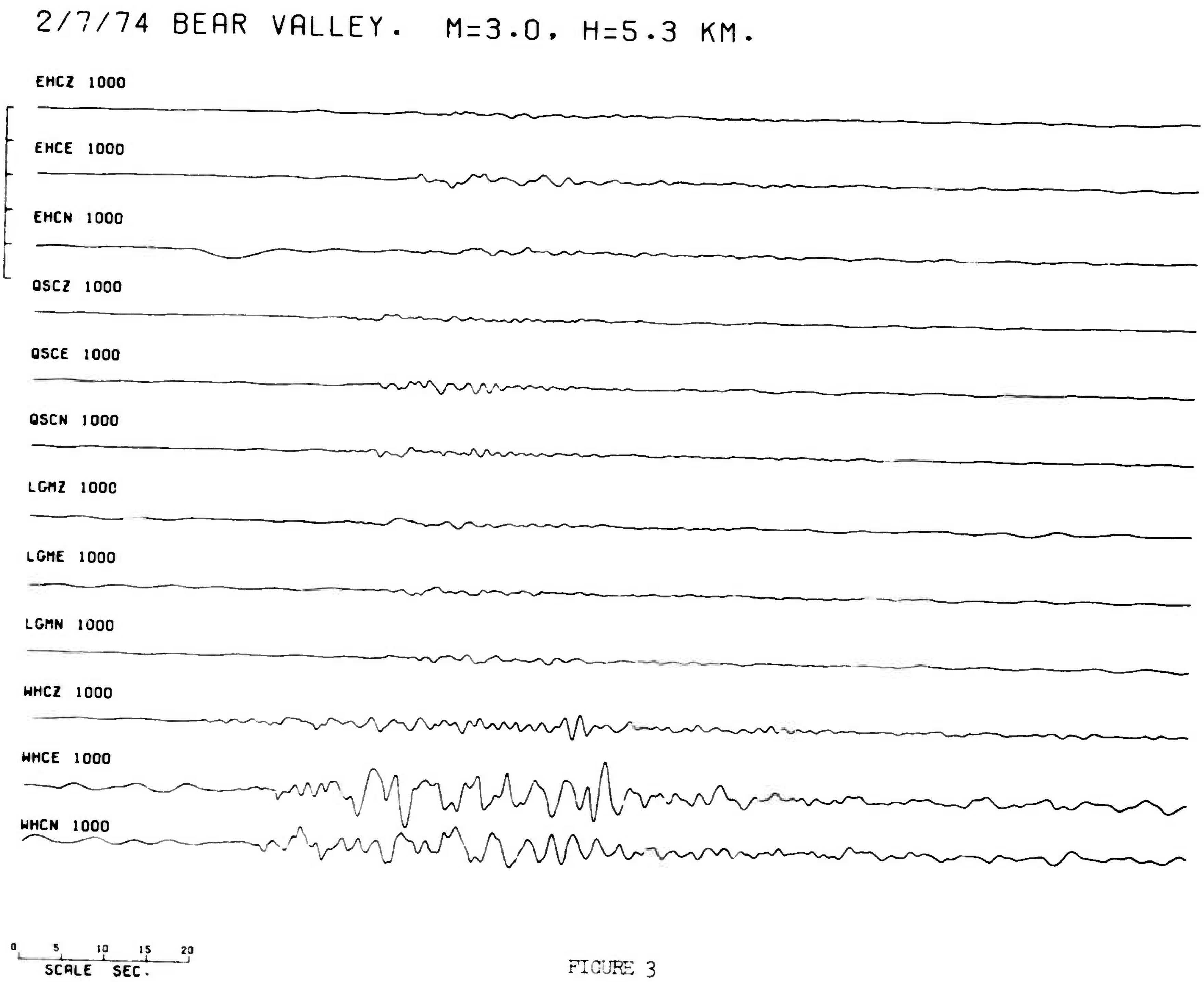

6/22/73 BEAR VALLEY. M=4.0, H=9.5 KM.
EHCE 2000
CSCN 2000
LGMZ 2000
LGME 2000
LGMN 2000
LGMR 2000
LGMT 2000
WHCZ 4000
WHCE 4000
WHCN 4000
WHCR 4000
WHCT 4000
MTCZ 1000
MTCE 1000
MTCN 1000
MTCR 1000
MTCT 1000
0
5
10
15
20
SCALE SEC.

FIGURE 2



2/7/74 BEAR VALLEY. M=3.0, H=5.3 KM.
EHCZ 1000
EHCE 1000
EHCN 1000
QSCZ 1000
QSCE 1000
QSCN 1000
LGMZ 1000
LGME 1000
LGMN 1000
WHCZ 1000
WHCE 1000
WHCN 1000
0 5 10 15 20
SCALE SEC.

FIGURE 3

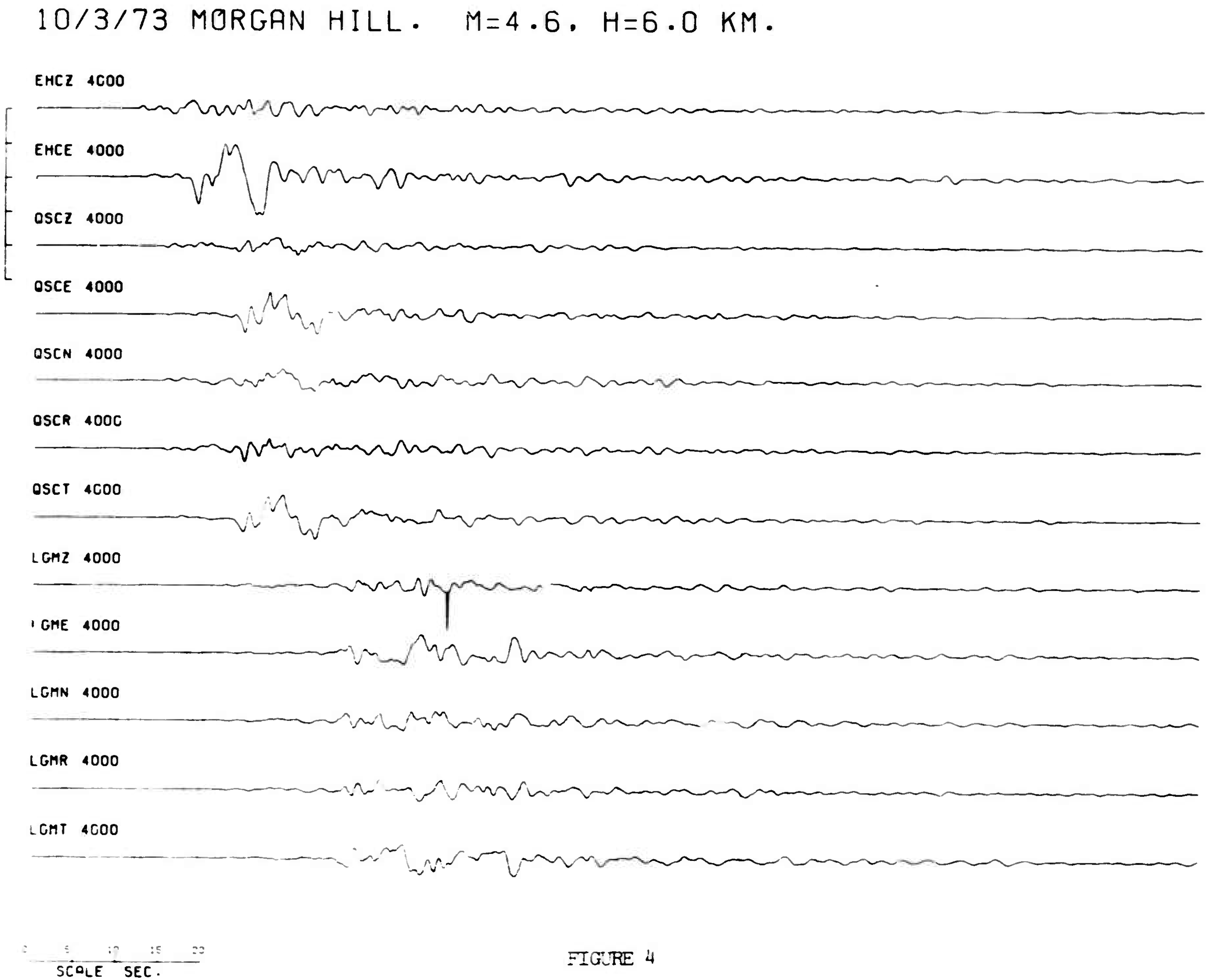

10/3/73 MØRGAN HILL. M=4.6. H=6.0 KM.
EHCZ 4000
EHCE 4000
QSCZ 4000
QSCE 4000
QSCN 4000
QSCR 4000
QSCT 4000
LGMZ 4000
LGME 4000
LGMN 4000
LGMR 4000
LGMT 4000
0 5 10 15 20
SCALE SEC.

FIGURE 4

10/3/73 MORGAN HILL. M=4.6. H=6.0 KM.

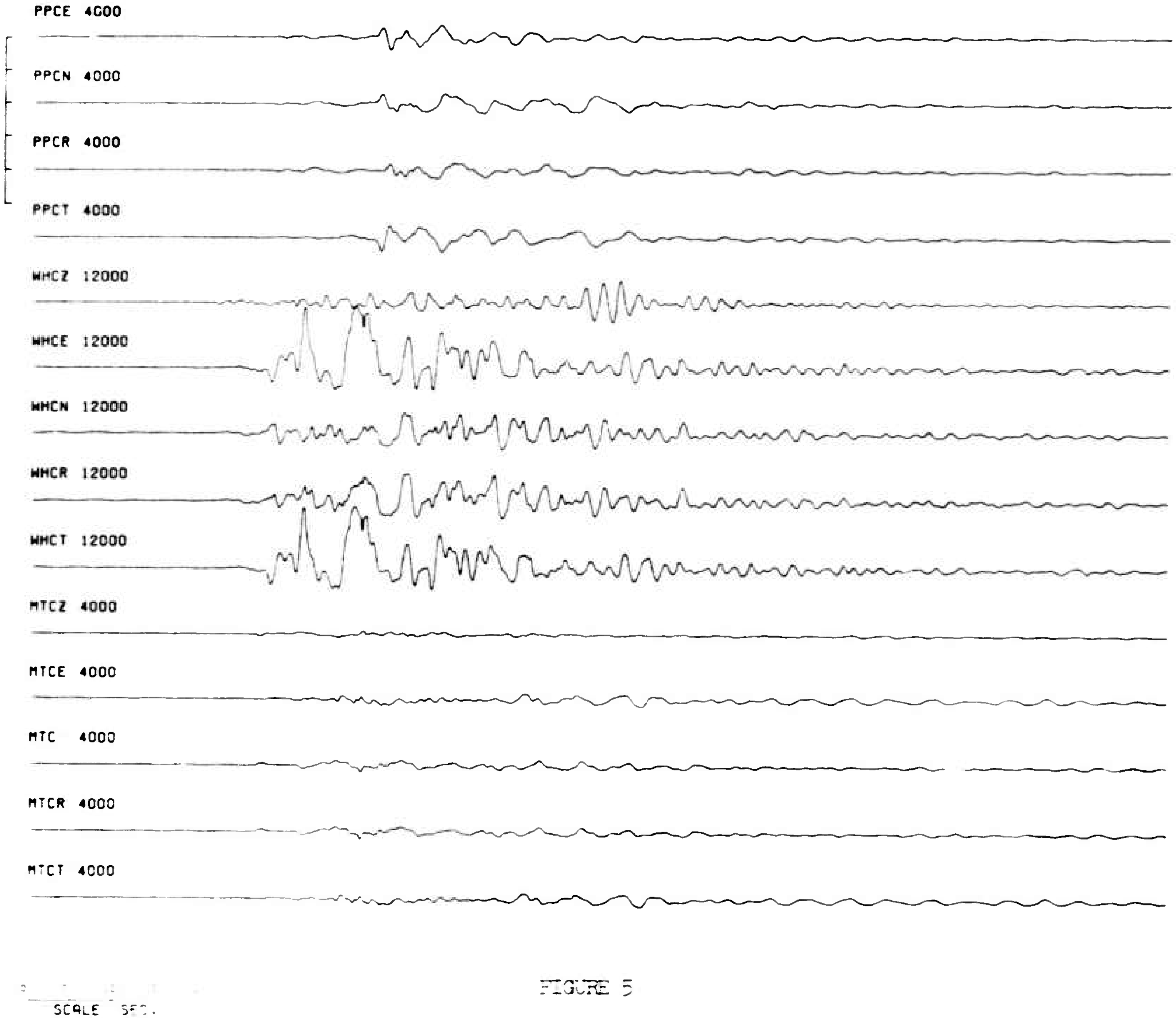


FIGURE 5

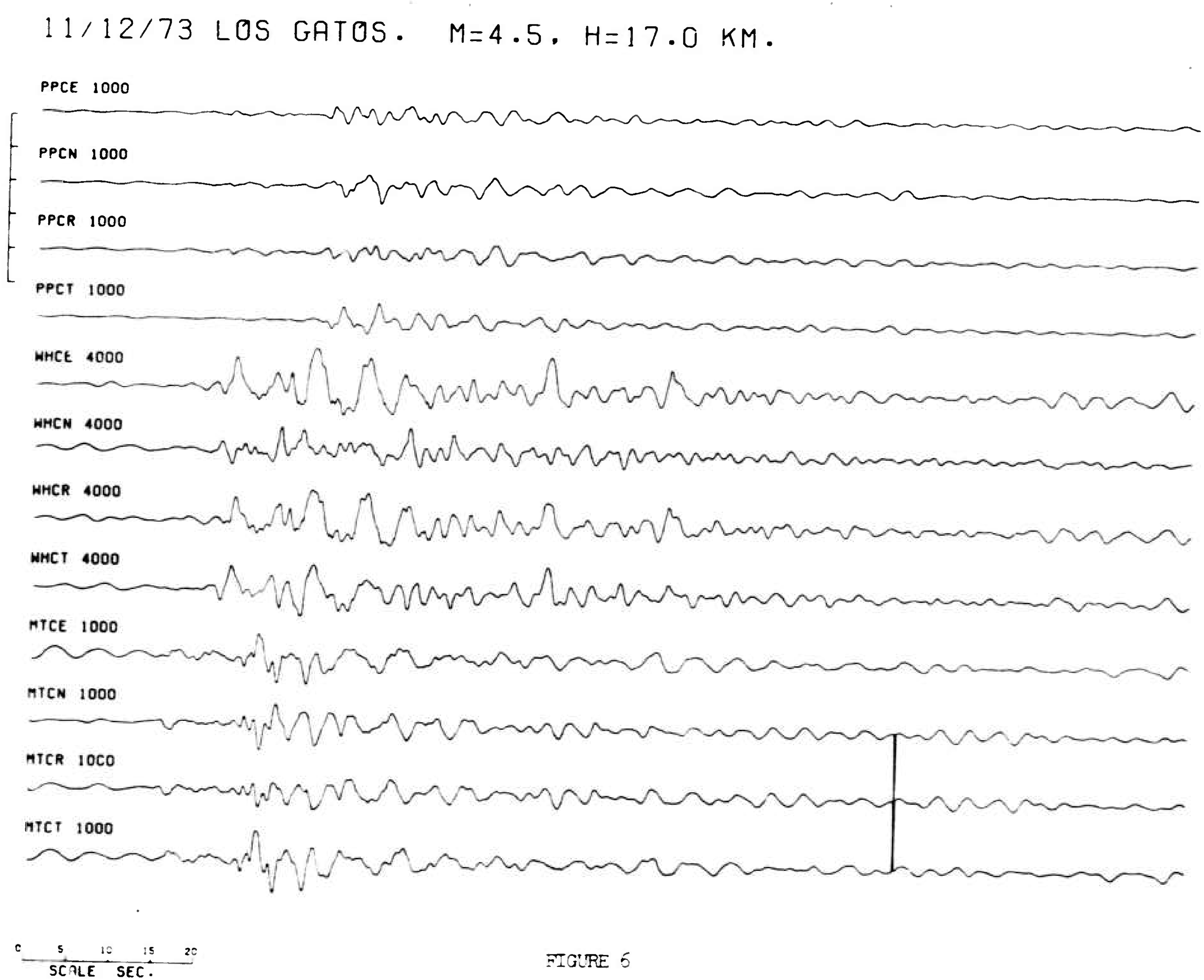

11/12/73 LØS GATØS. M=4.5. H=17.0 KM.
PPCE 1000
PPCN 1000
PPCR 1000
PPCT 1000
WHCE 4000
WHCN 4000
WHCR 4000
WHCT 4000
MTCE 1000
MTCN 1000
MTCR 10C0
MTCT 1000
0 5 10 15 20
SCALE SEC.

FIGURE 6

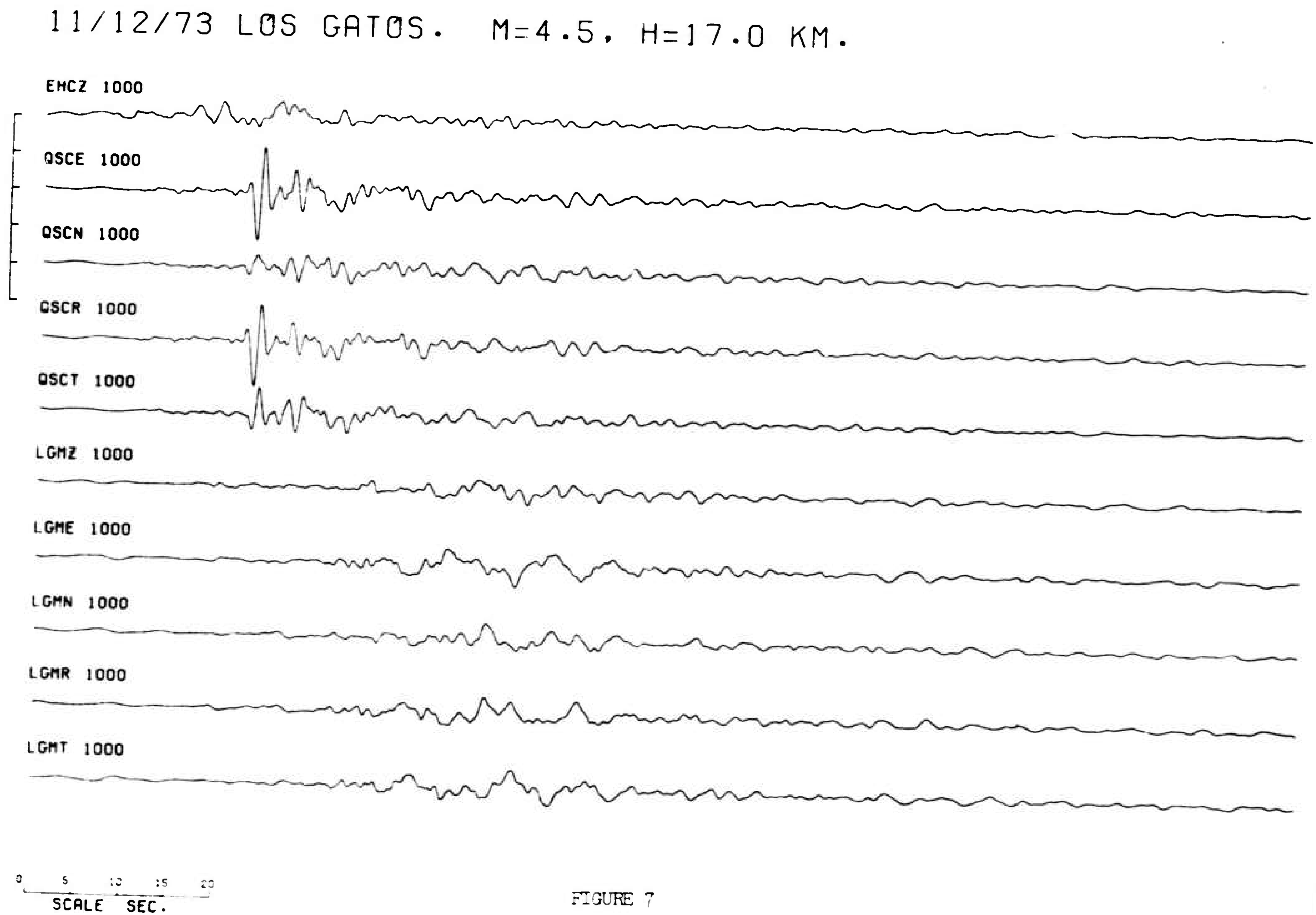

11/12/73 LØS GATØS. M=4.5. H=17.0 KM.
EHCZ 1000
QSCE 1000
QSCN 1000
QSCR 1000
QSCT 1000
LGMZ 1000
LGME 1000
LGMN 1000
LGMR 1000
LGMT 1000
0 5 10 15 20
SCALE SEC.

FIGURE 7

2/1/74 QUARRY EQ. M=3.4, H=4.0 KM.

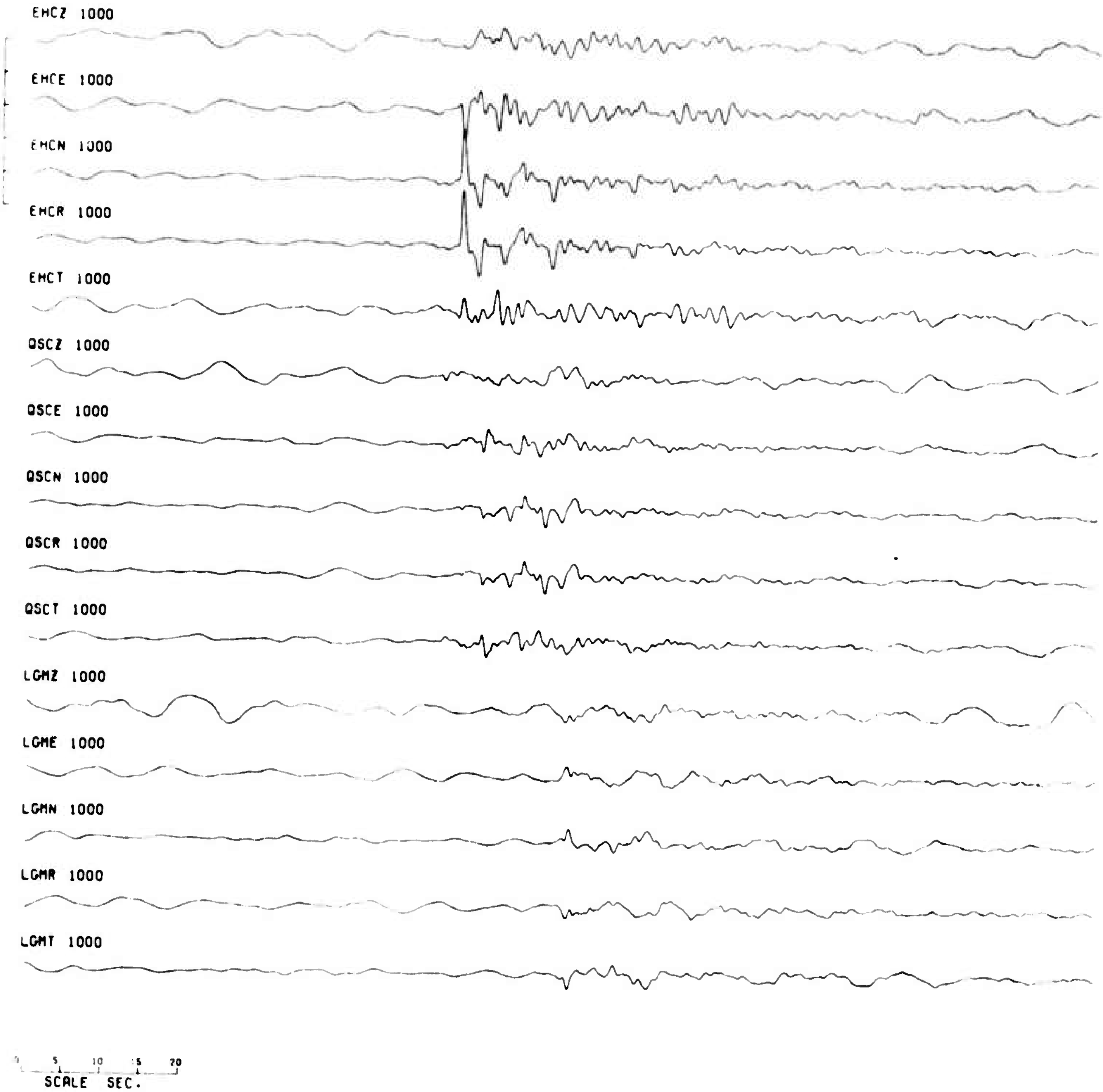


FIGURE 8

2/1/74 QUARRY EQ. M=3.4, H=4.0 KM.

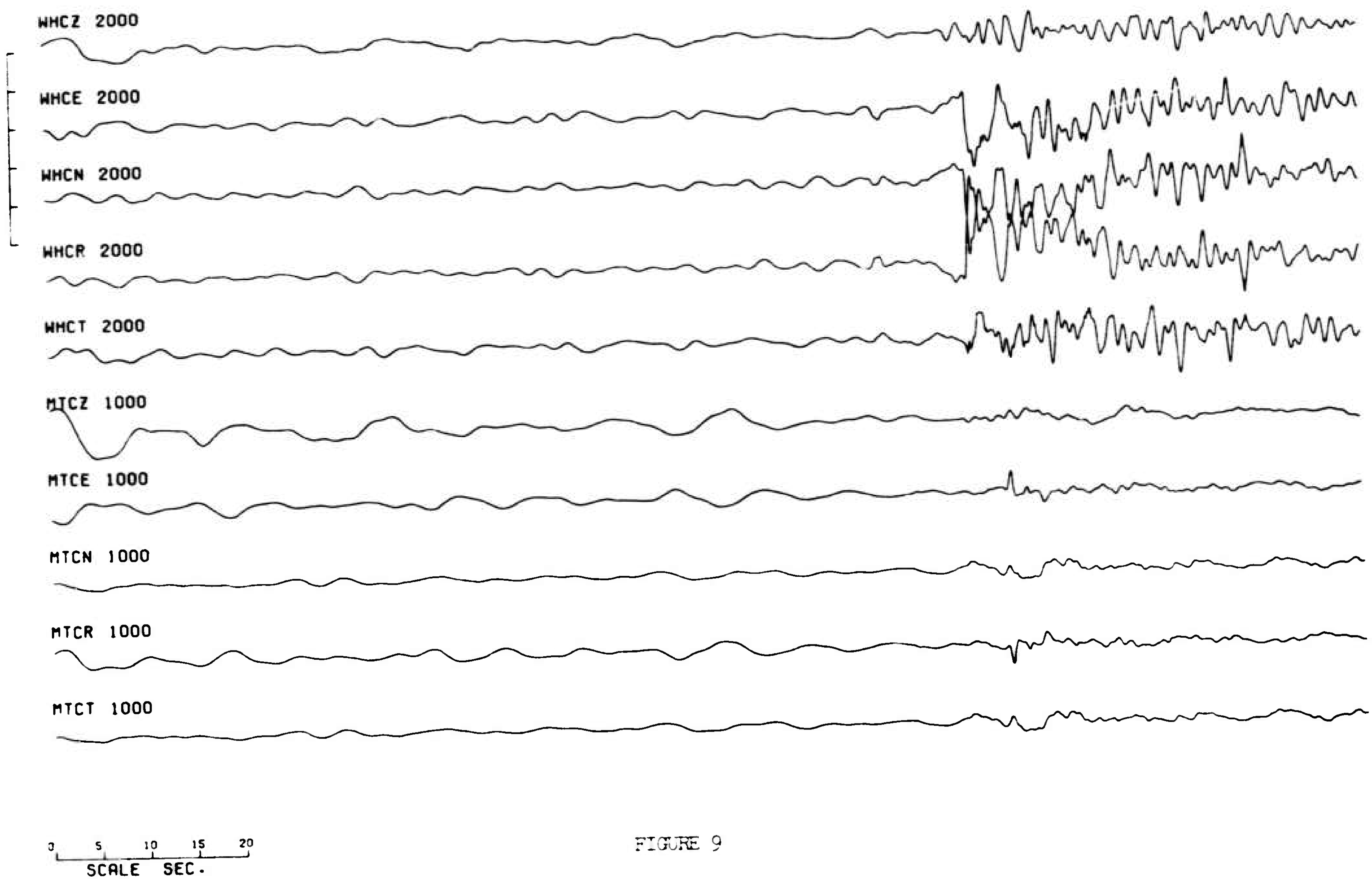
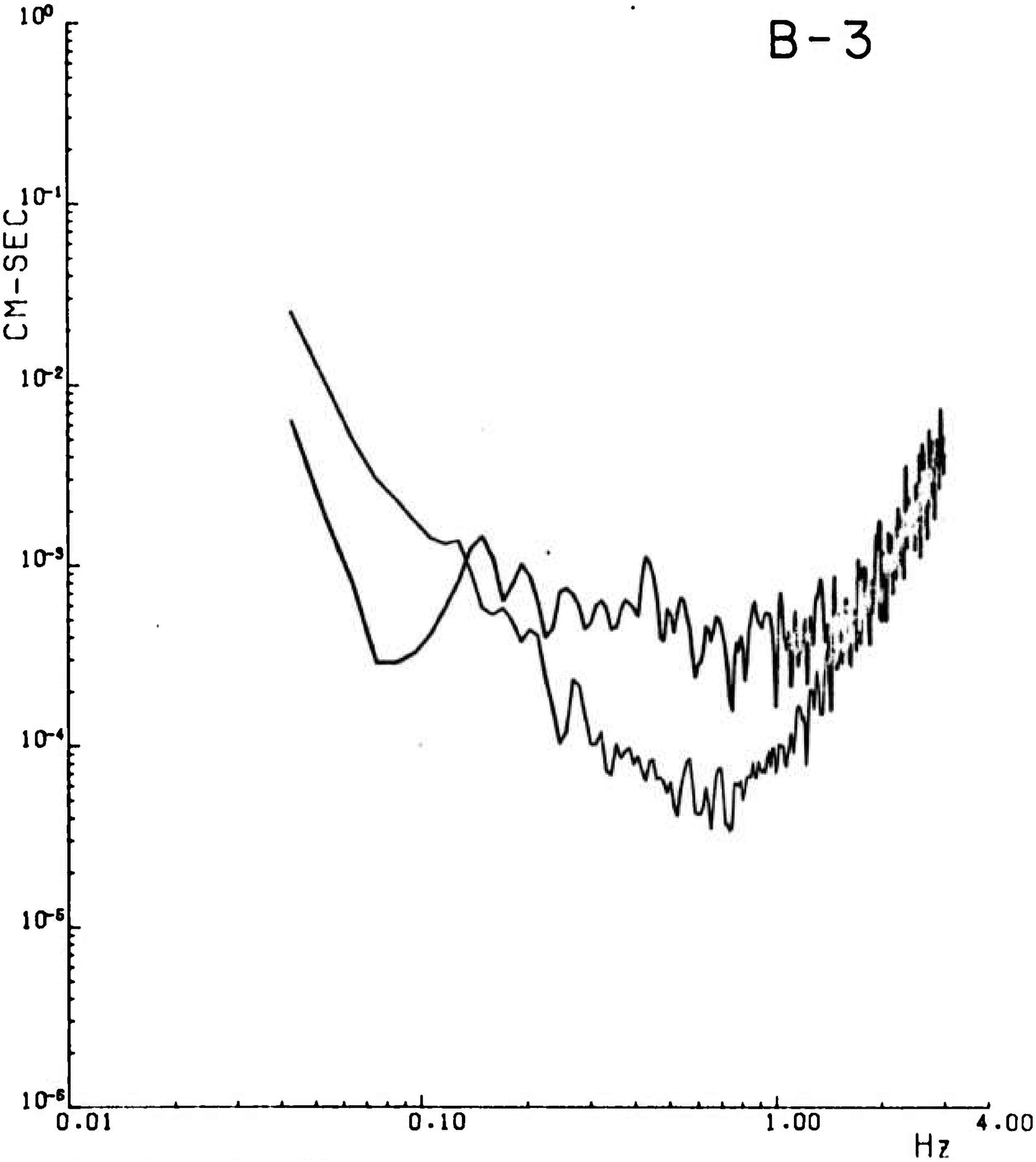


FIGURE 9



EHCN 2/7/74 BEAR VALLEY M3.0 H5.3 D38.2 AZ163

FIGURE 10

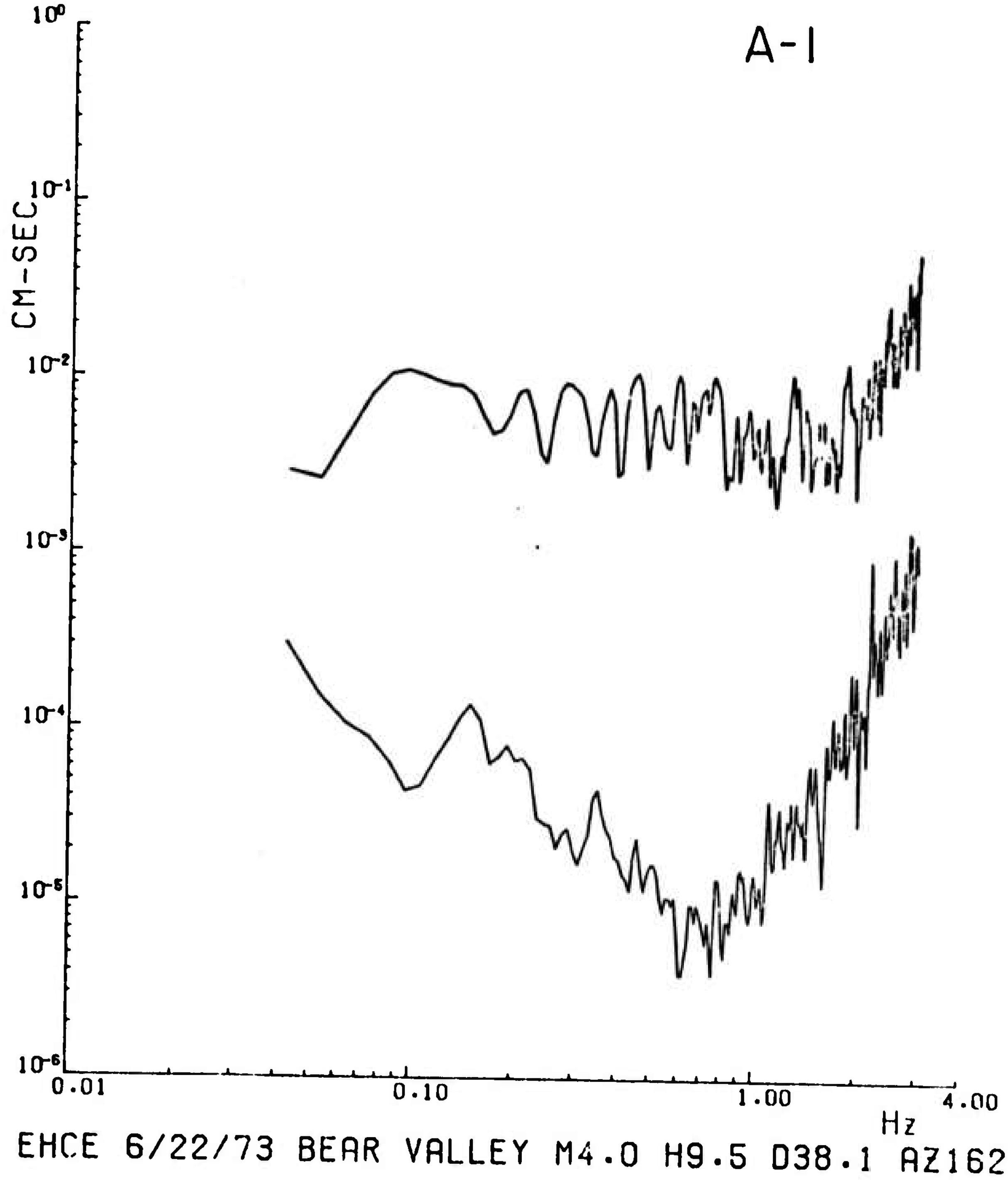
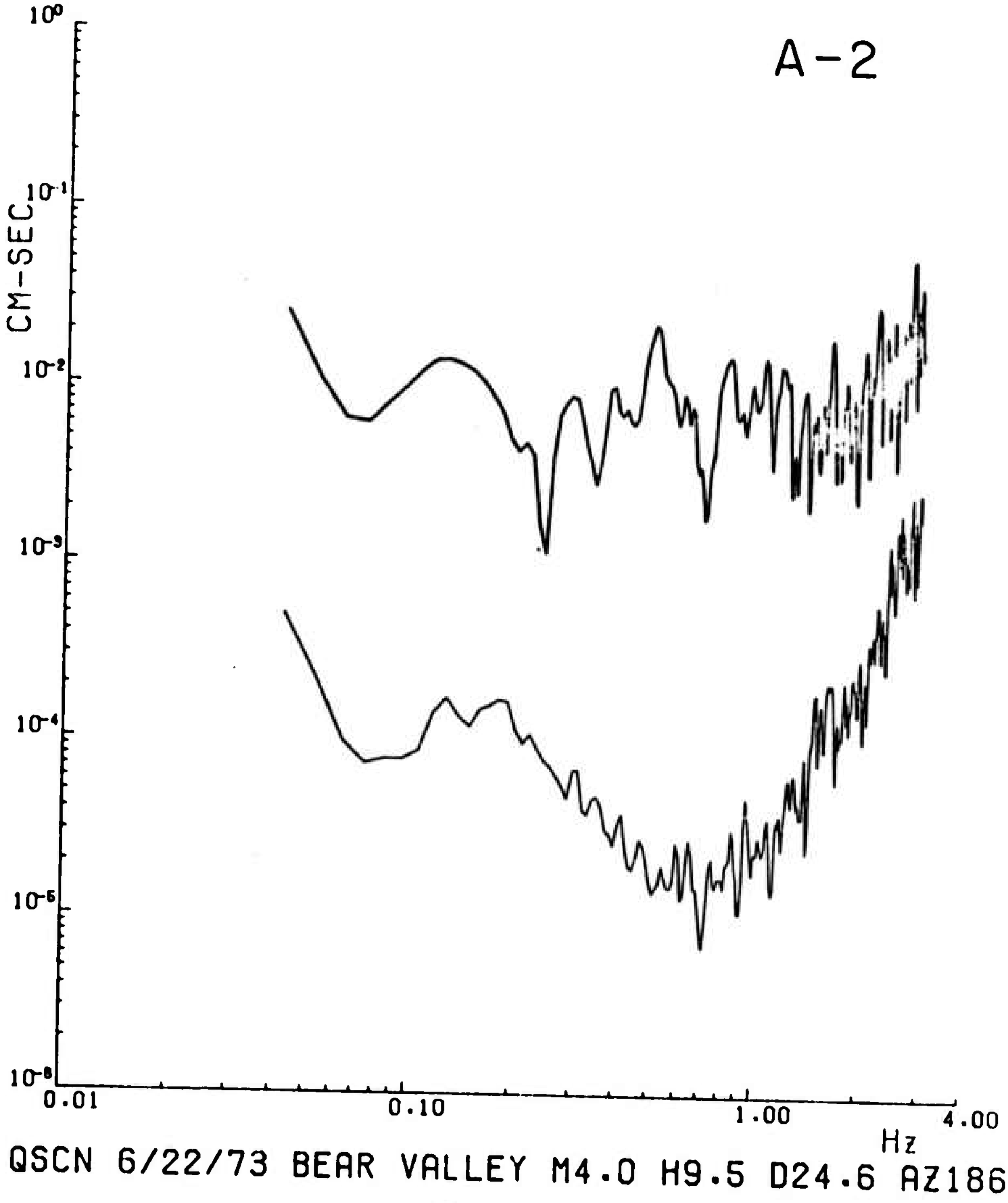

A-1
CM-SEC
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
EHCE 6/22/73 BEAR VALLEY M4.0 H9.5 D38.1 AZ162

FIGURE 11



A-2
CM-SEC
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
QSCN 6/22/73 BEAR VALLEY M4.0 H9.5 D24.6 AZ186

FIGURE 12

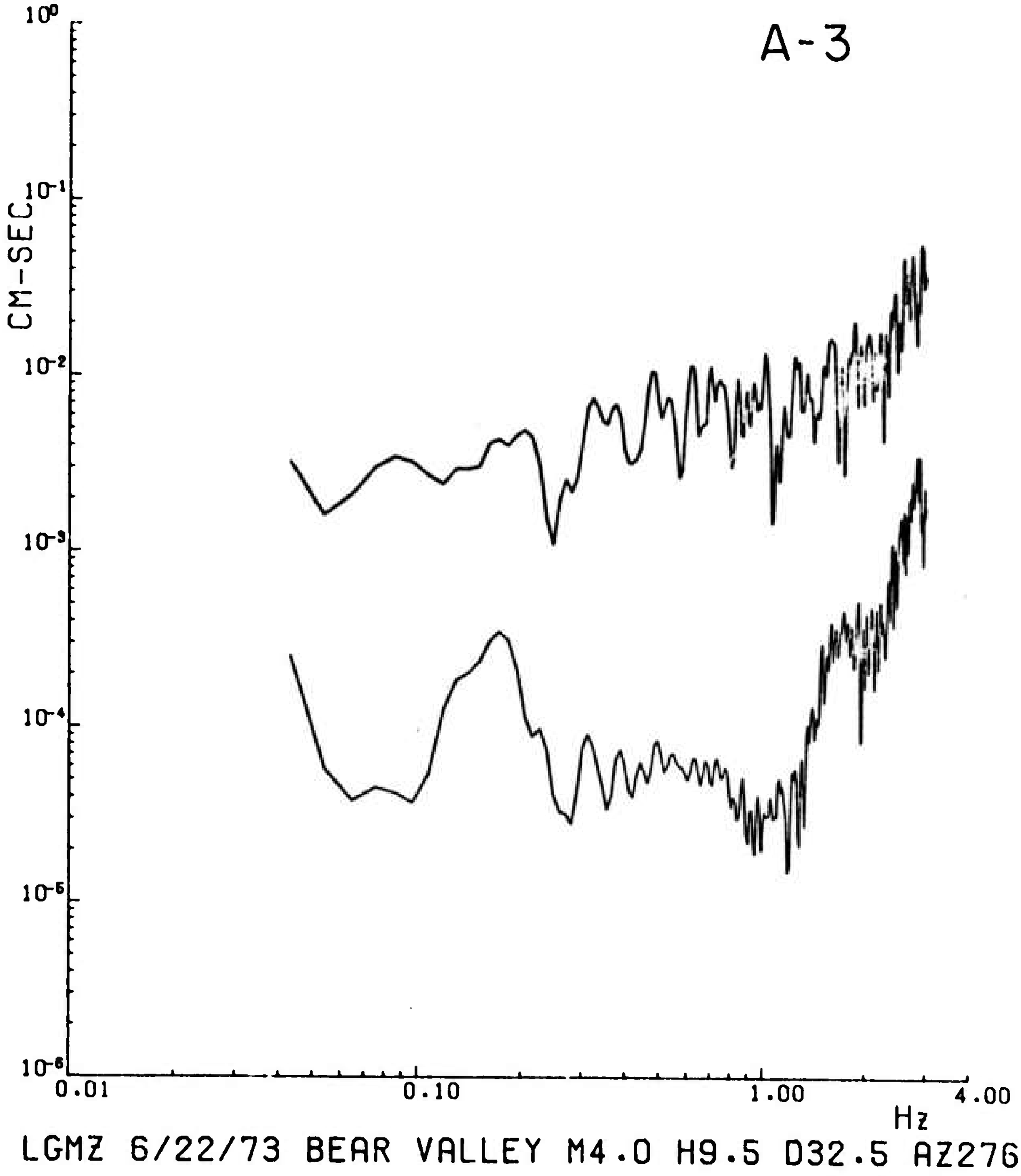

A-3
CM-SEC
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
LGMZ 6/22/73 BEAR VALLEY M4.0 H9.5 D32.5 AZ276

FIGURE 13

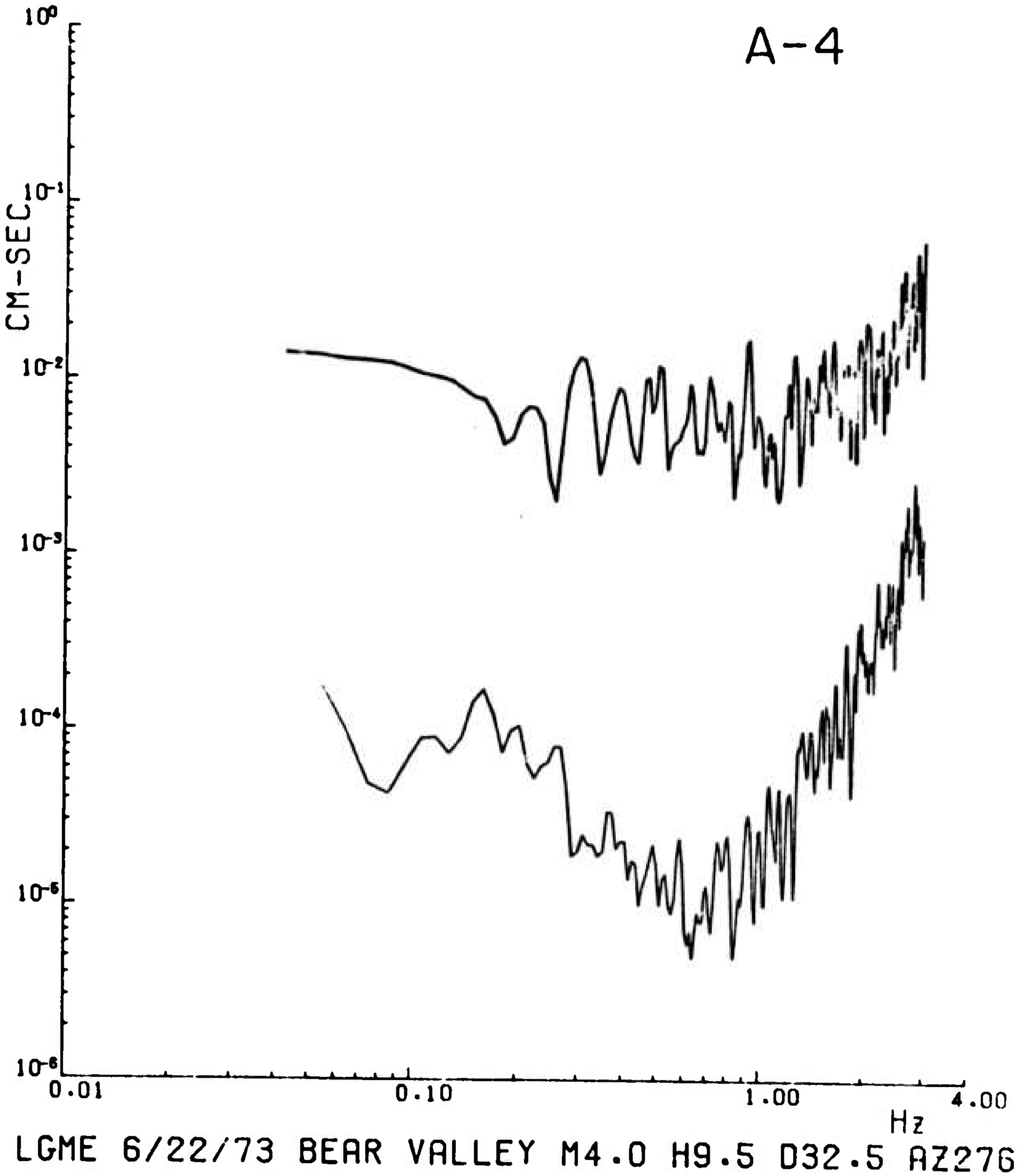

A-4
CM-SEC
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
LGME 6/22/73 BEAR VALLEY M4.0 H9.5 D32.5 AZ276

FIGURE 14

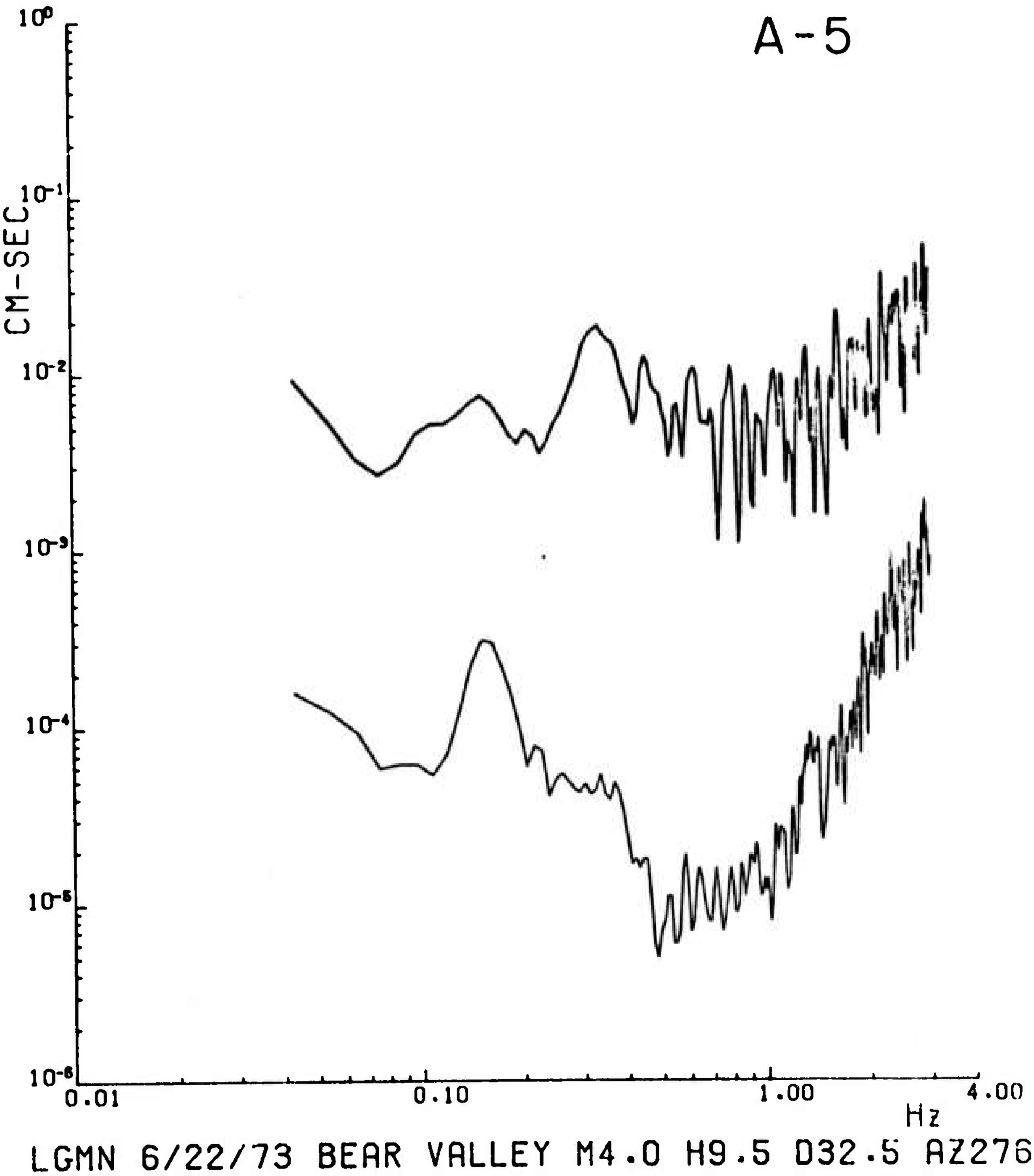
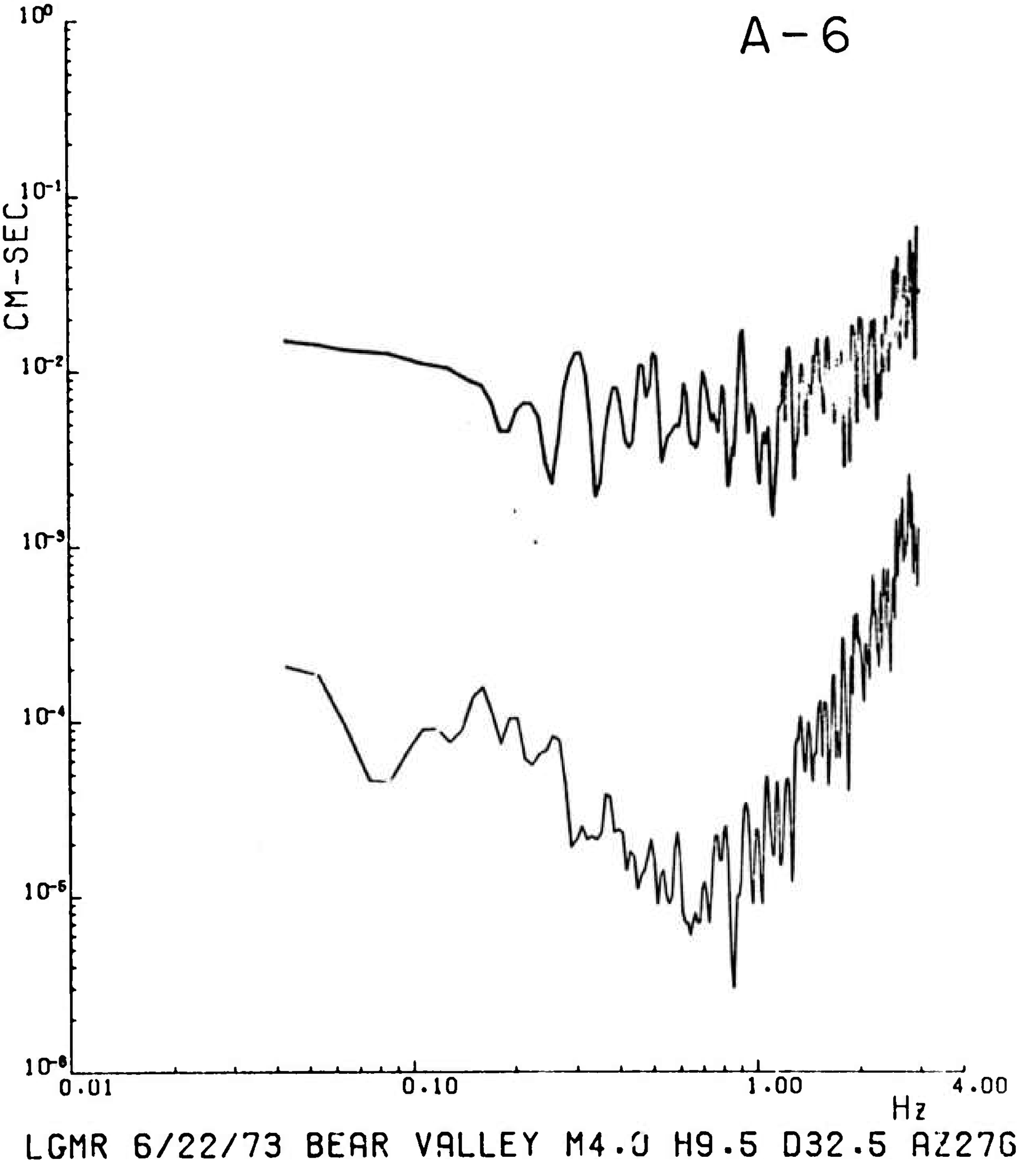

A-5
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
CM-SEC
0.01
0.10
1.00
4.00
Hz
LGMN 6/22/73 BEAR VALLEY M4.0 H9.5 D32.5 AZ276

FIGURE 15



A-6
CM-SEC
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
LGMR 6/22/73 BEAR VALLEY M4.0 H9.5 D32.5 AZ276

FIGURE 16

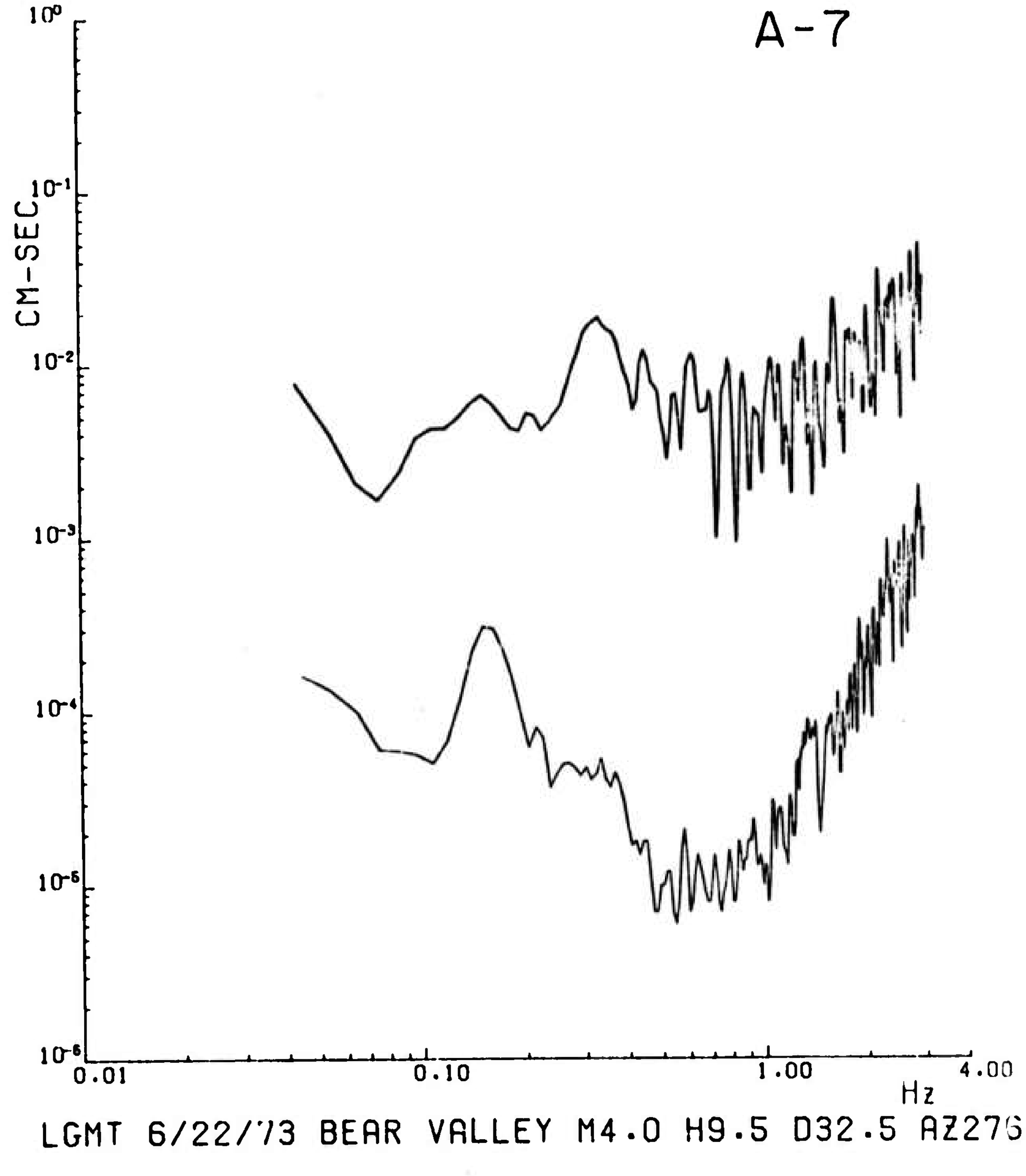

A-7
CM-SEC
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
LGMT 6/22/73 BEAR VALLEY M4.0 H9.5 D32.5 AZ276

FIGURE 17

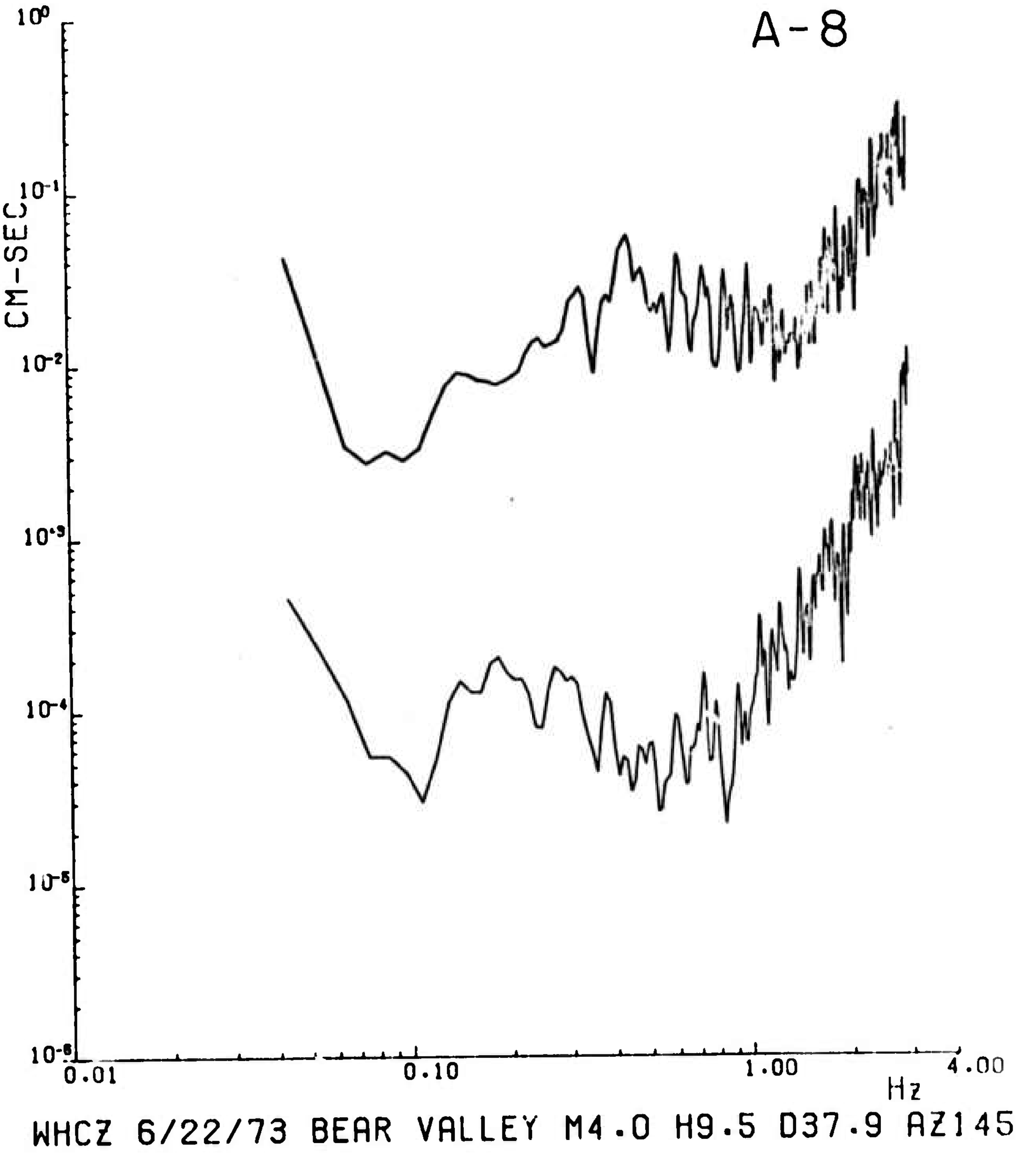

A-8
CM-SEC
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
WHCZ 6/22/73 BEAR VALLEY M4.0 H9.5 D37.9 AZ145

FIGURE 18

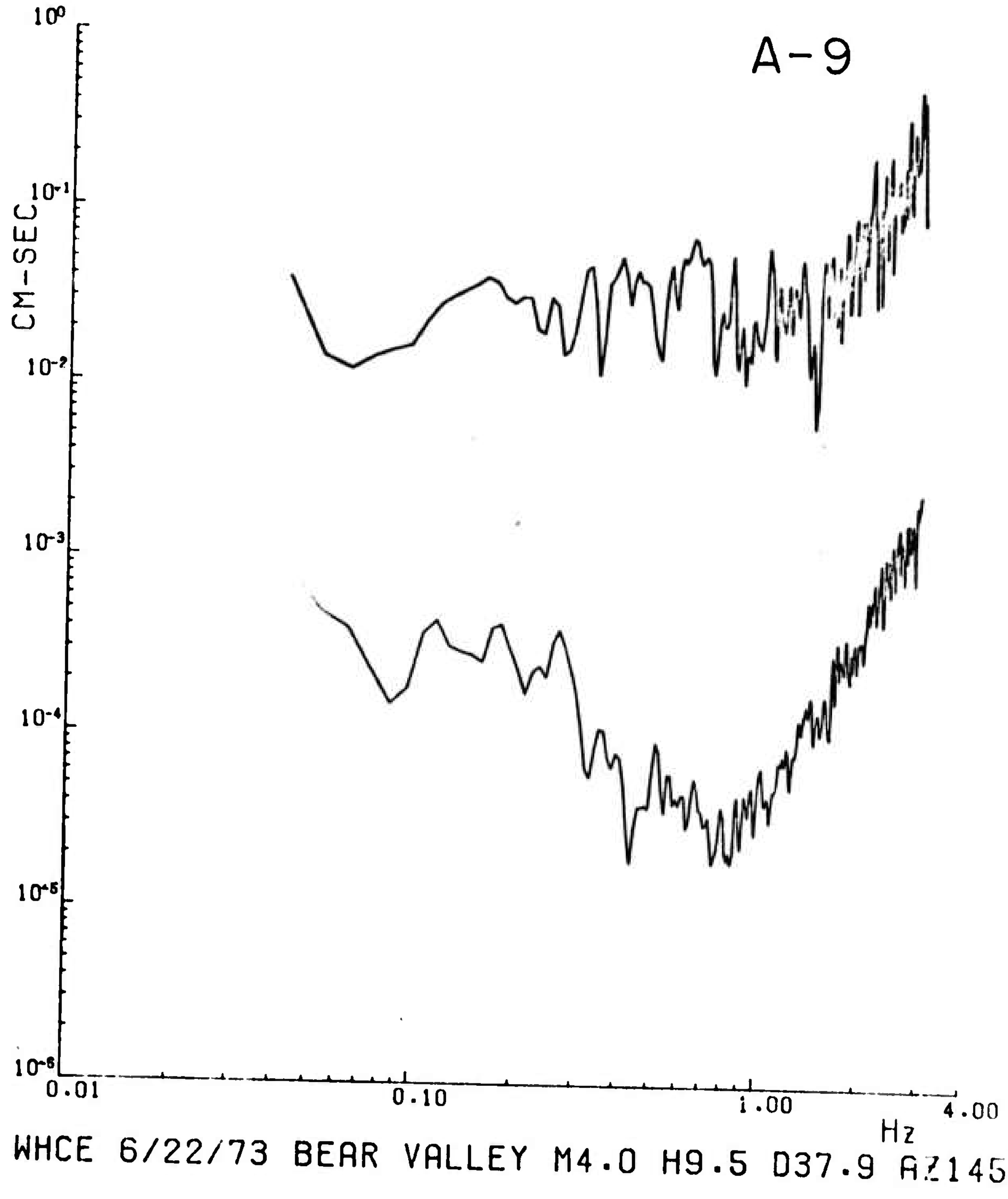

A-9
CM-SEC
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
WHCE 6/22/73 BEAR VALLEY M4.0 H9.5 D37.9 AZ145

FIGURE 19

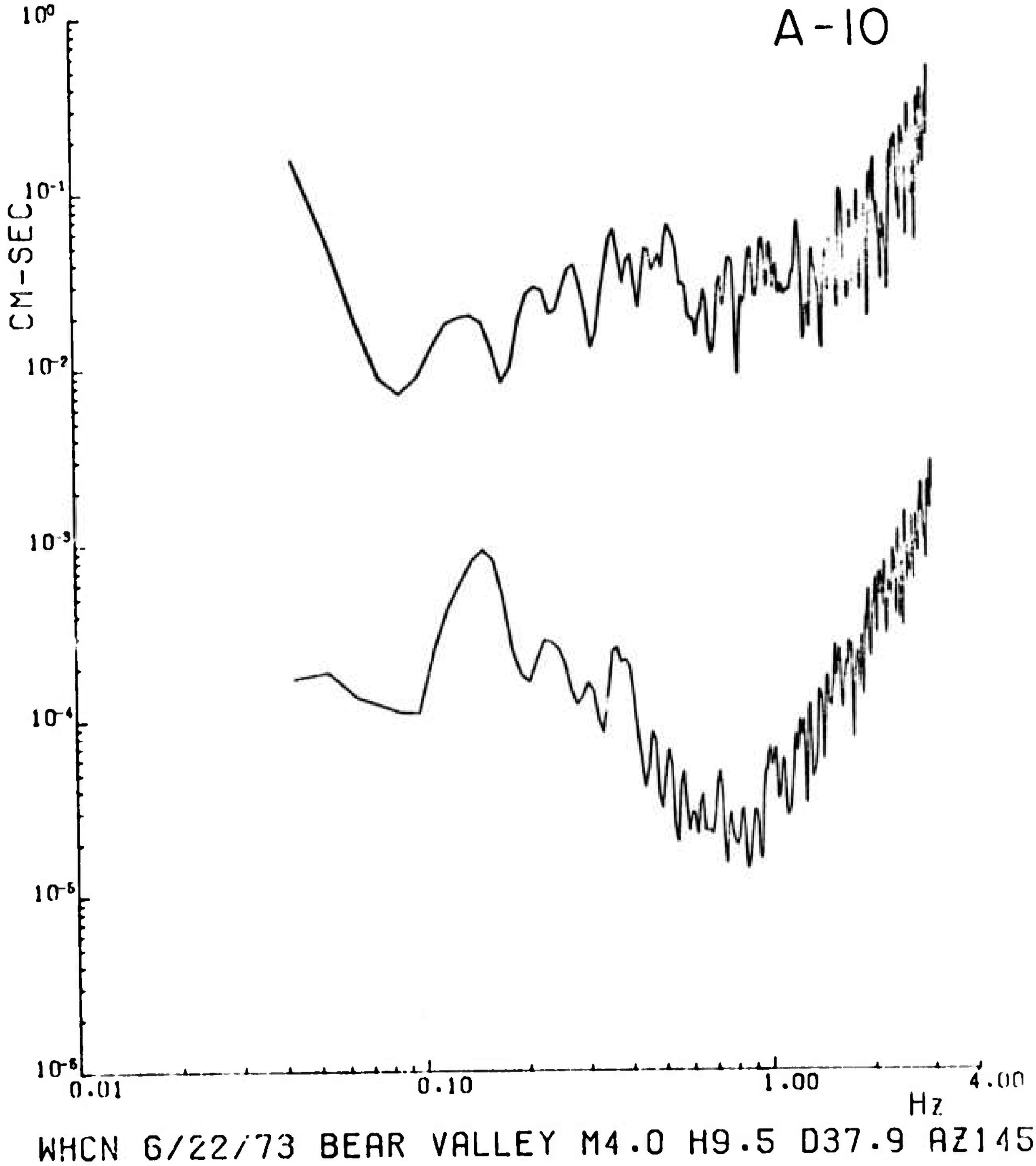

A-10
CM-SEC
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
0.01
0.10
1.00
4.00
Hz
WHCN 6/22/73 BEAR VALLEY M4.0 H9.5 D37.9 AZ145

FIGURE 20

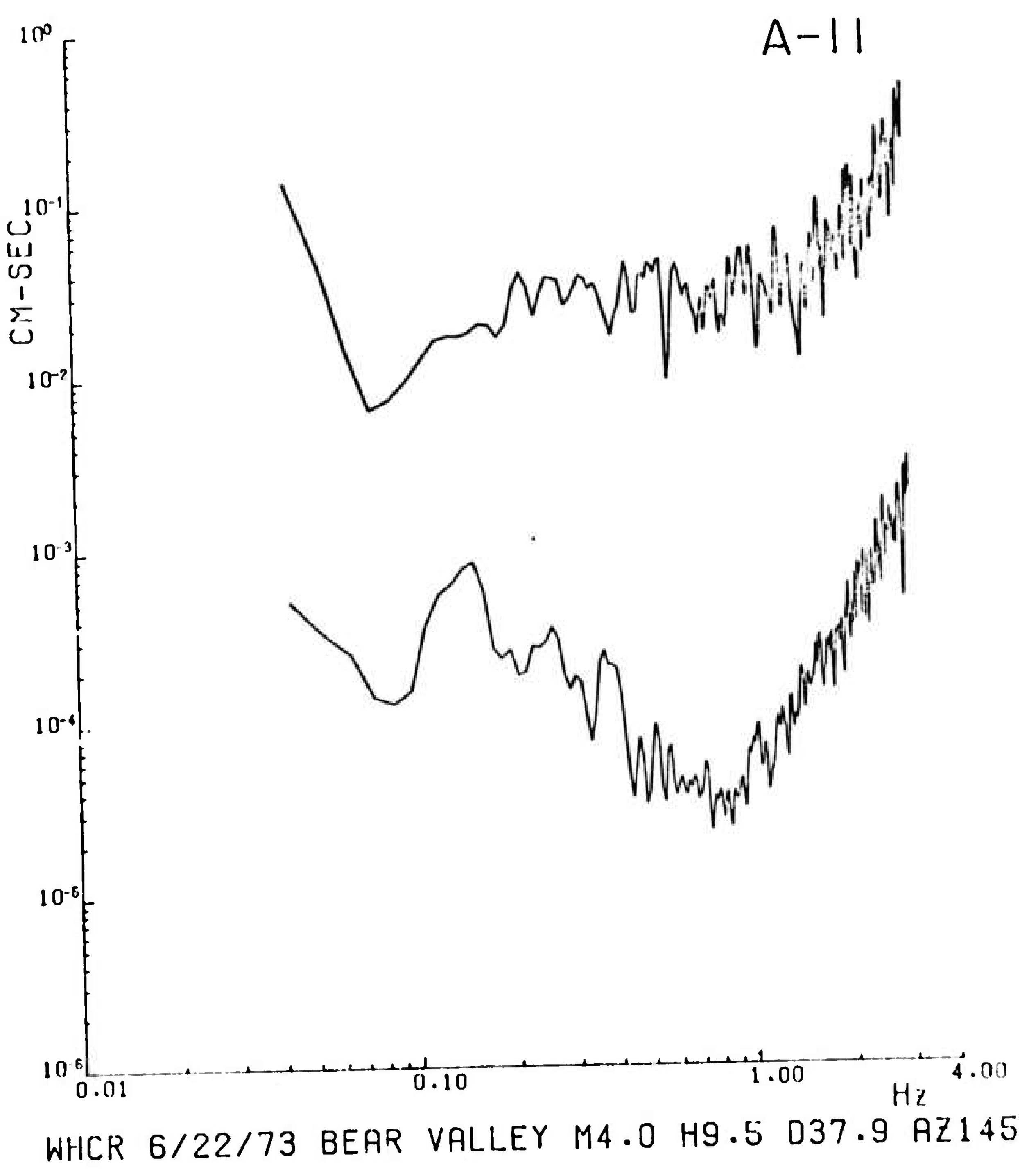
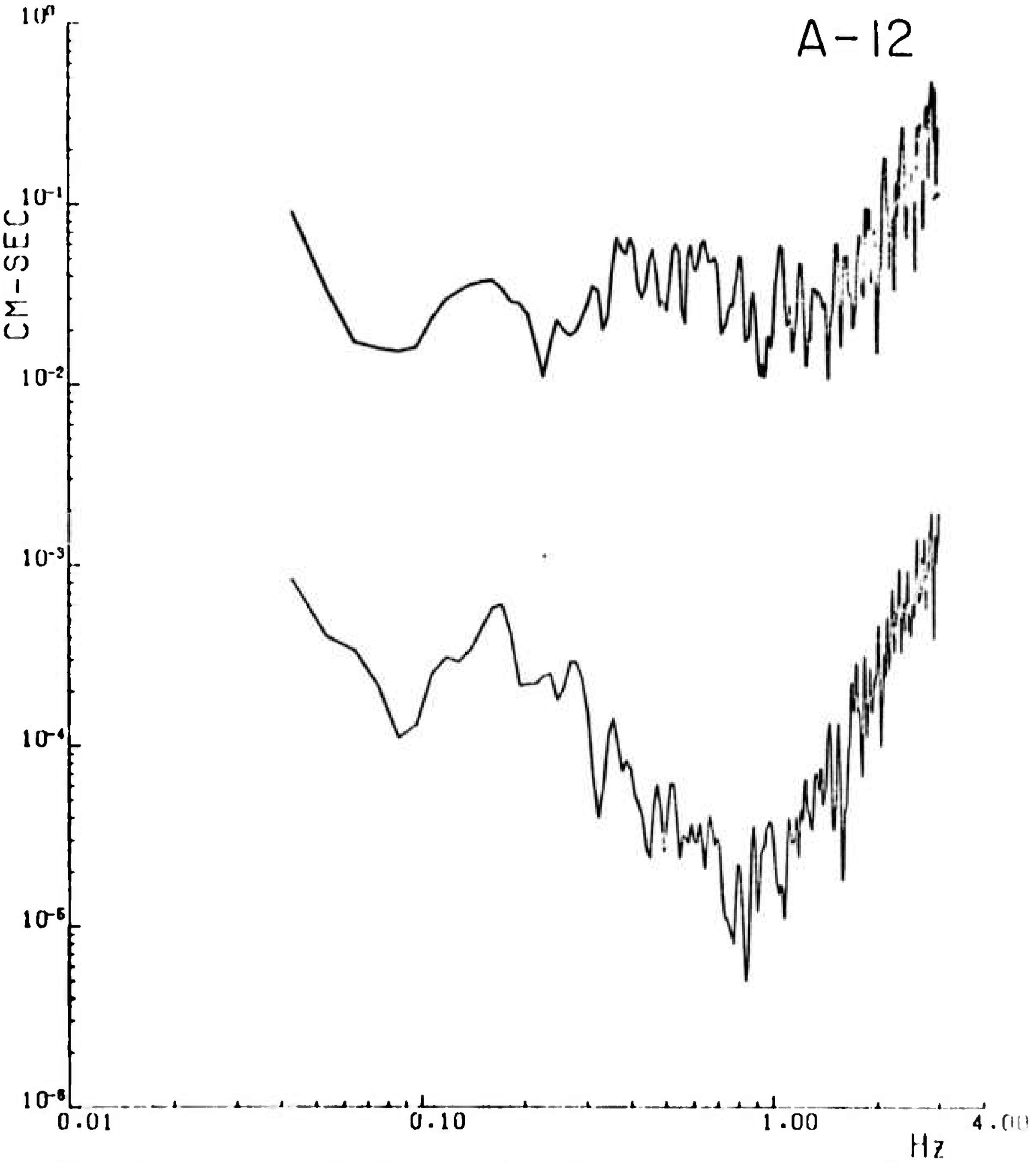
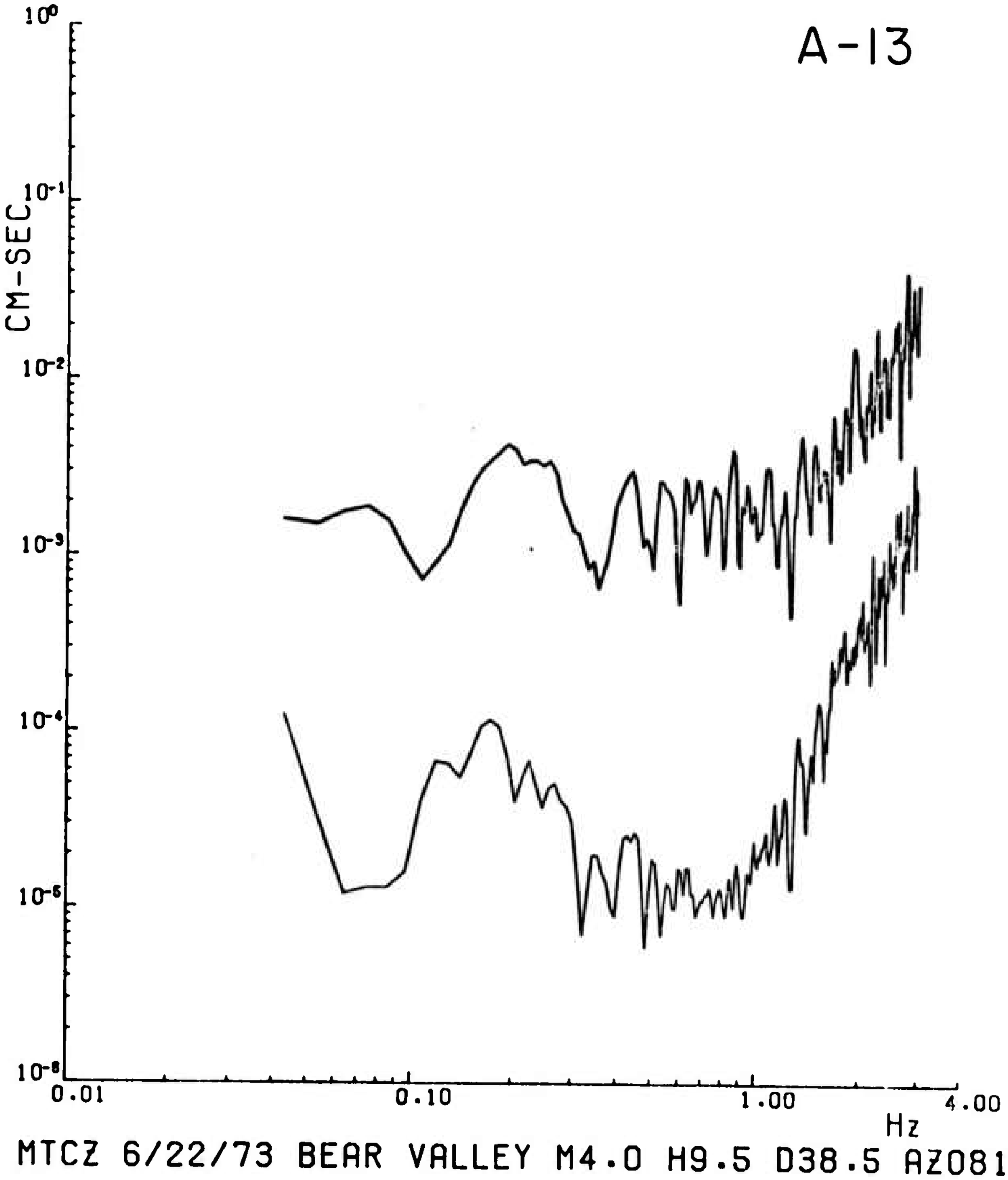

A-11
CM-SEC
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
0.01
0.10
1.00
4.00
Hz
WHCR 6/22/73 BEAR VALLEY M4.0 H9.5 D37.9 AZ145

FIGURE 21



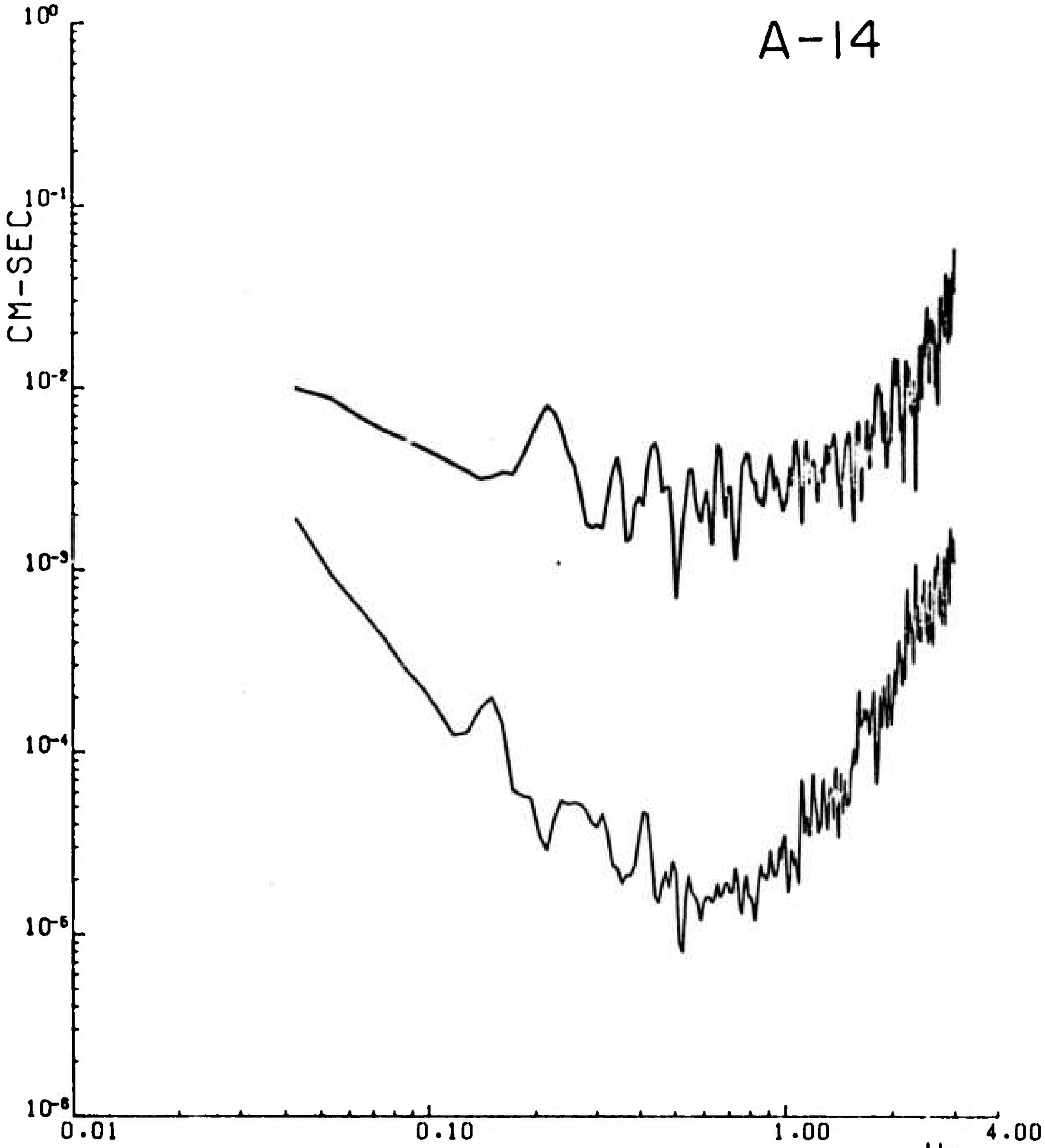
WHCT 6/22/73 BEAR VALLEY M4.0 H9.5 D37.9 AZ145

FIGURE 22



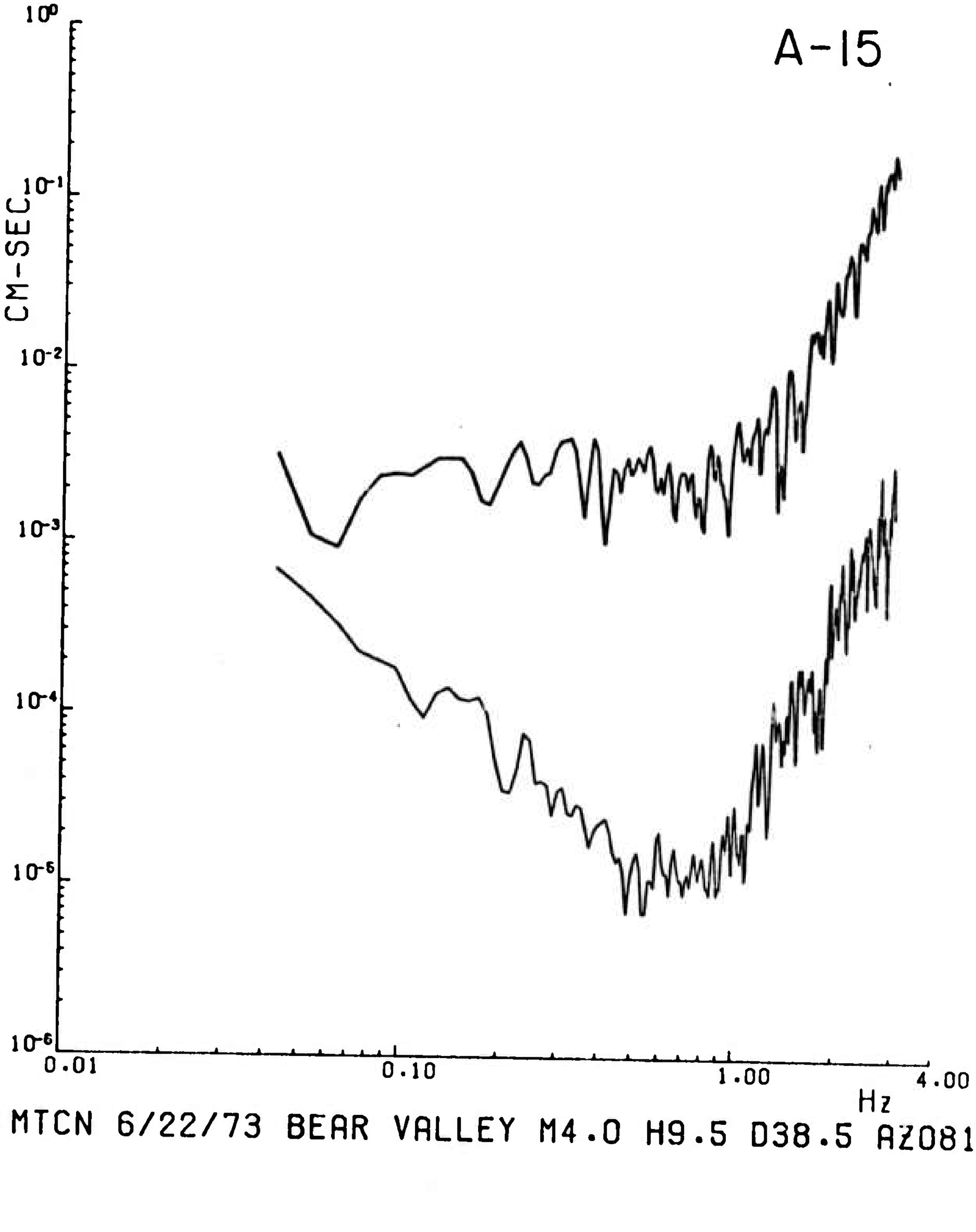
A-13
10^{0}
10^{-1}
CM-SEC
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
MTCZ 6/22/73 BEAR VALLEY M4.0 H9.5 D38.5 AZ081

FIGURE 23



MTCE 6/22/73 BEAR VALLEY M4.0 H9.5 D38.5 AZ081

FIGURE 24



A-15
CM-SEC
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
0.01
0.10
1.00
4.00
Hz
MTCN 6/22/73 BEAR VALLEY M4.0 H9.5 D38.5 AZ081

FIGURE 25

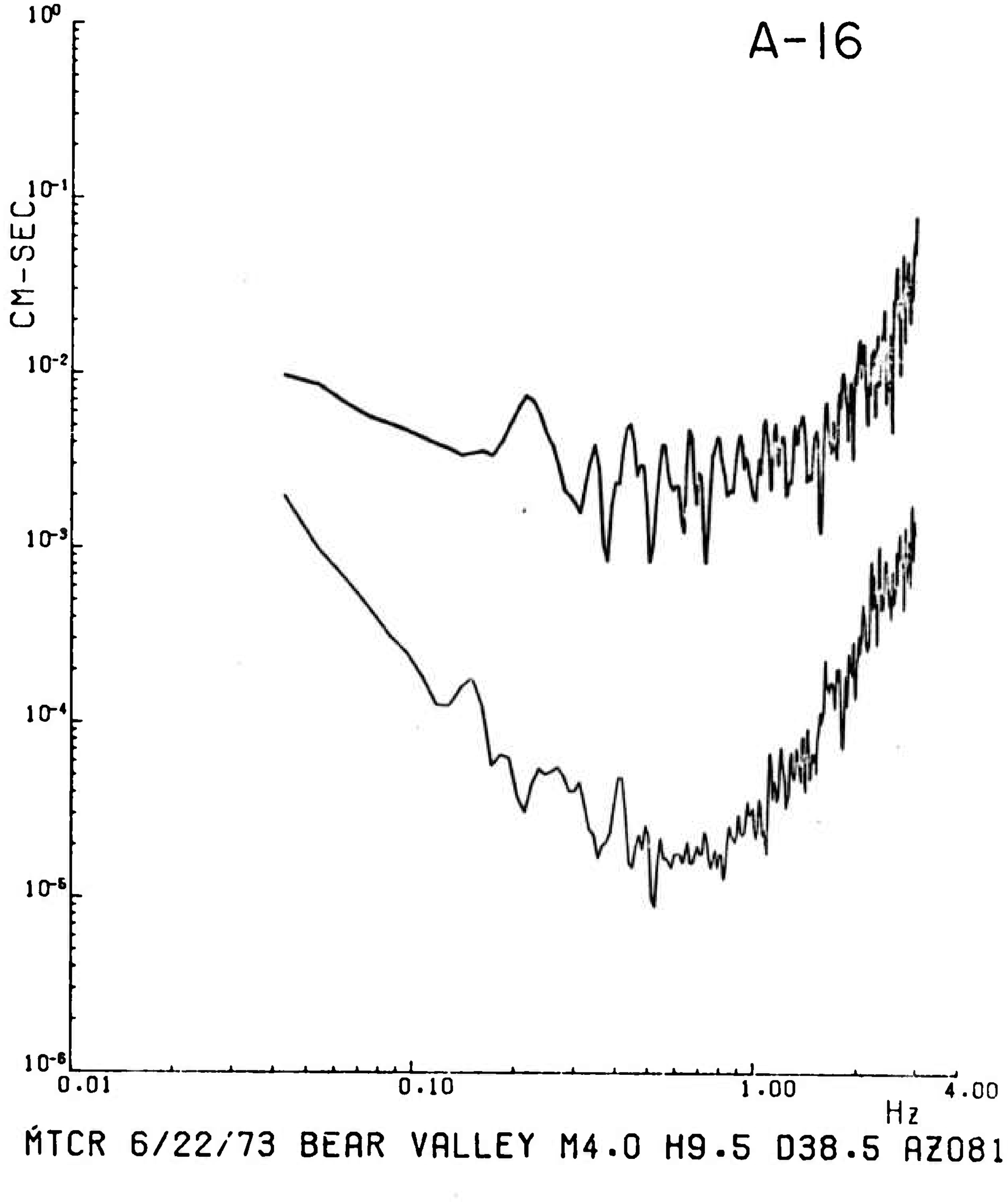
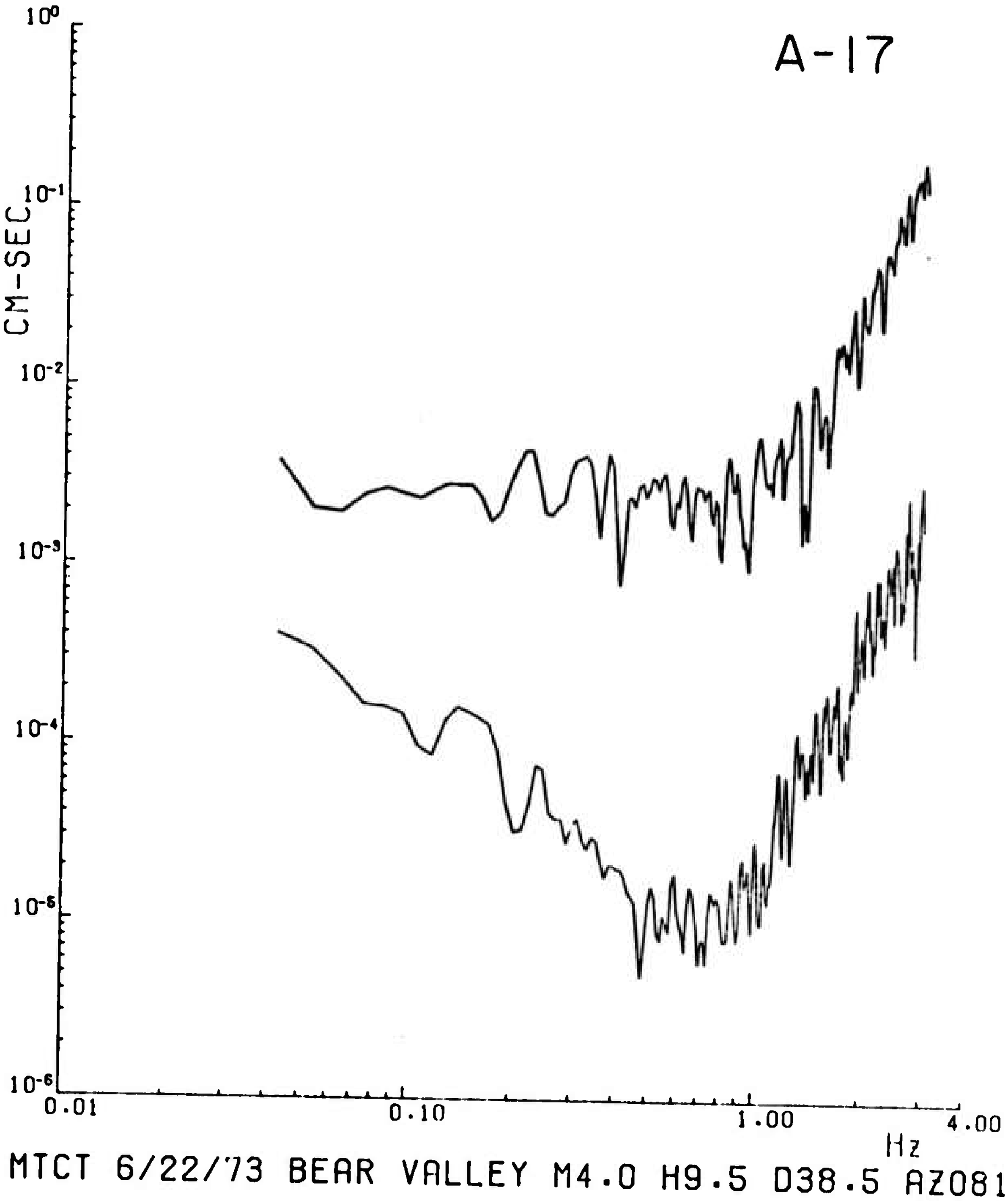
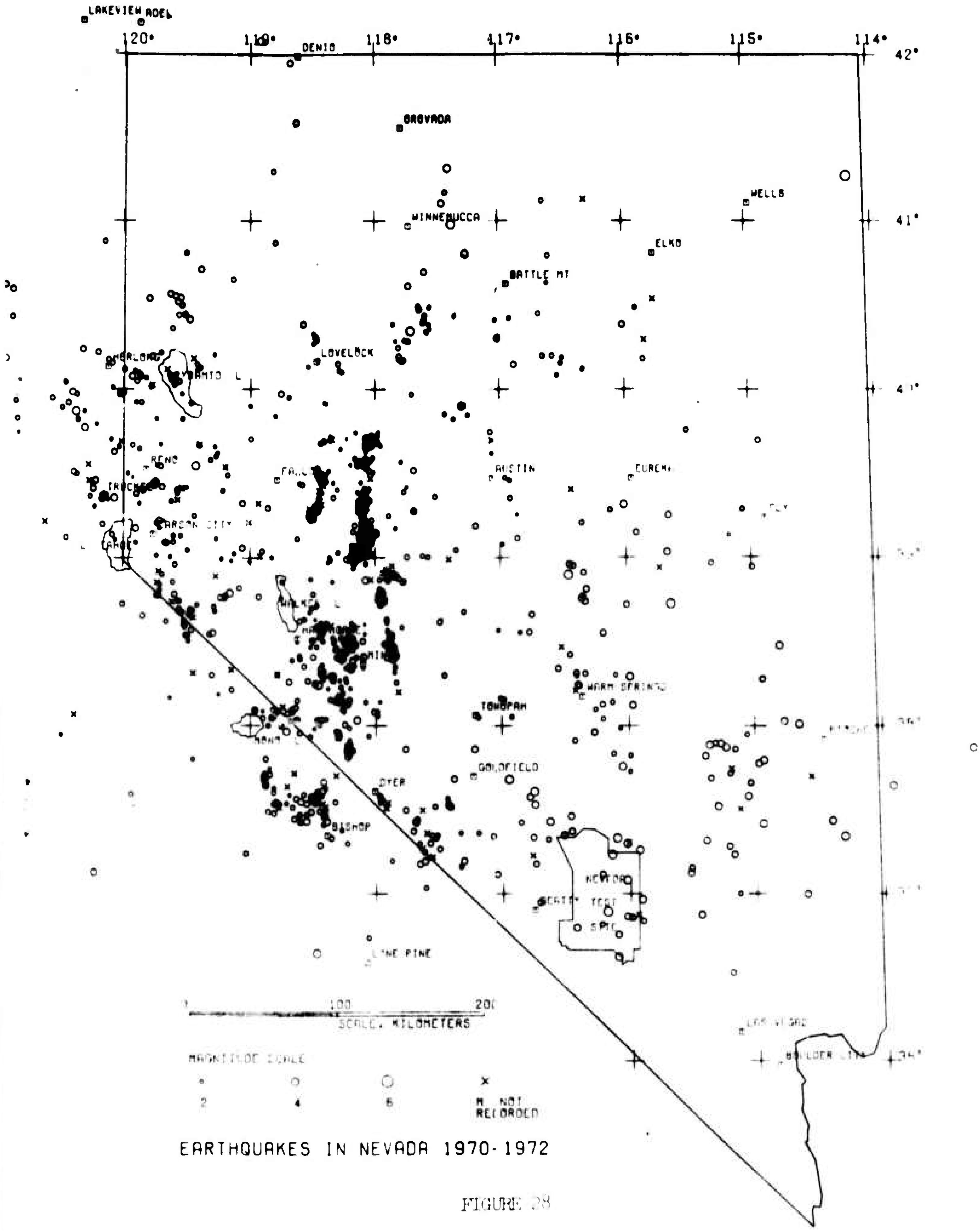

A-16
CM-SEC
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
0.01
0.10
1.00
4.00
Hz
MTCR 6/22/73 BEAR VALLEY M4.0 H9.5 D38.5 AZ081

FIGURE 26



A-17
CM-SEC
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.10
1.00
4.00
Hz
MTCT 6/22/73 BEAR VALLEY M4.0 H9.5 D38.5 AZ081

FIGURE 27



EARTHQUAKES IN NEVADA 1970-1972

FIGURE 28

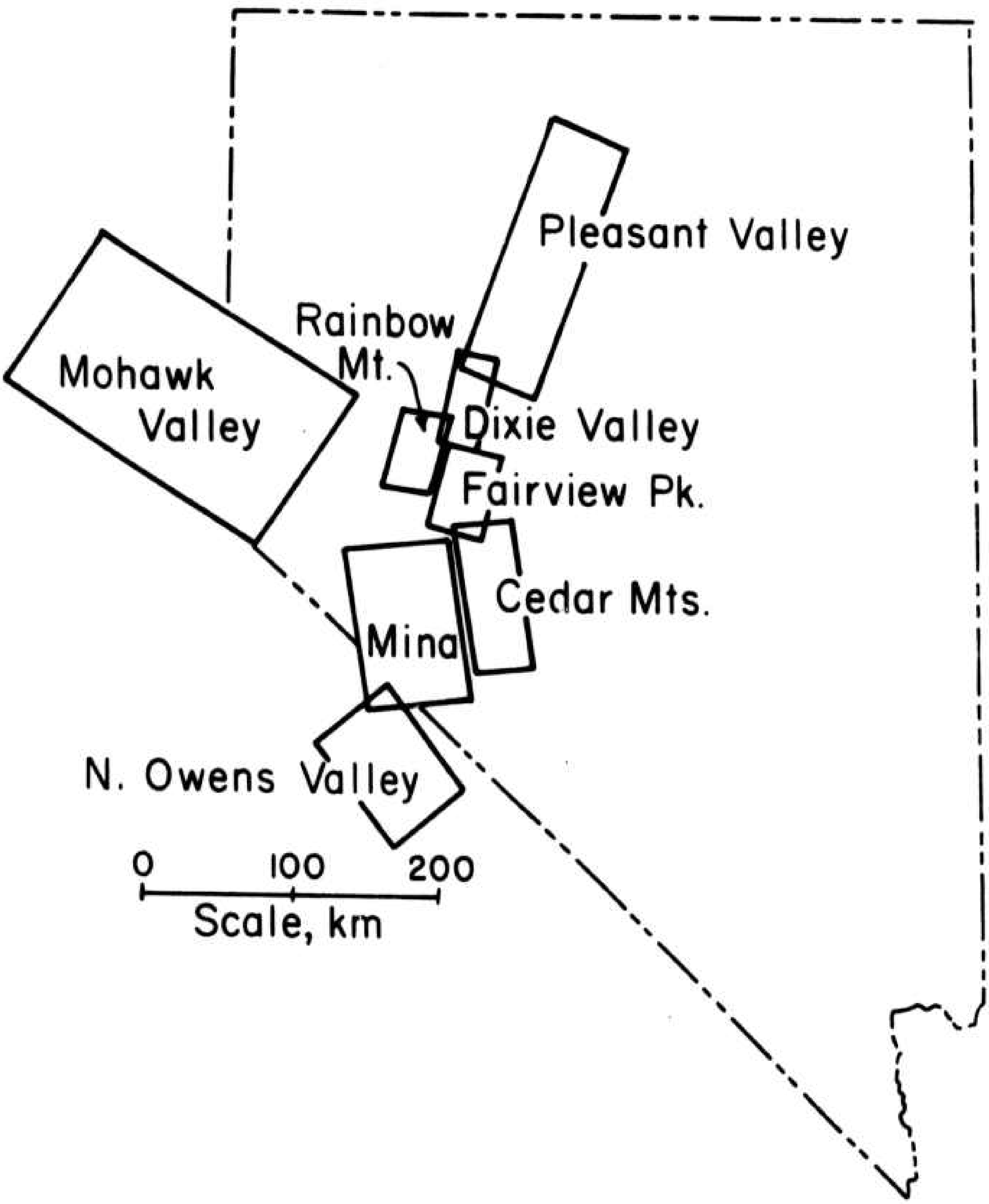

Pleasant Valley
Rainbow
Mt.
Mohawk
Valley
Dixie Valley
Fairview Pk.
Cedar Mts.
Mina
N. Owens Valley
0
100
200
Scale, km

FIGURE 29

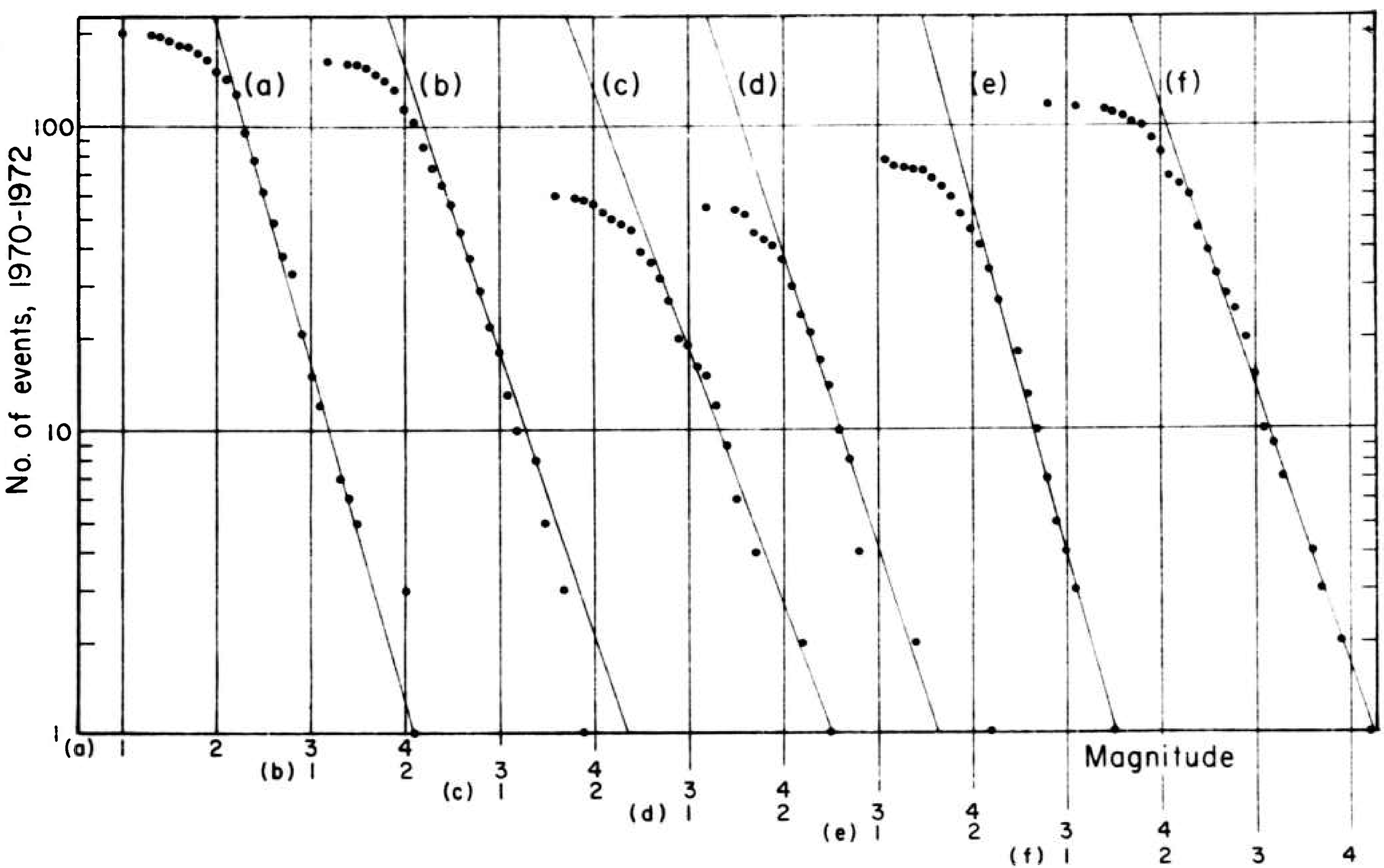


FIGURE 30

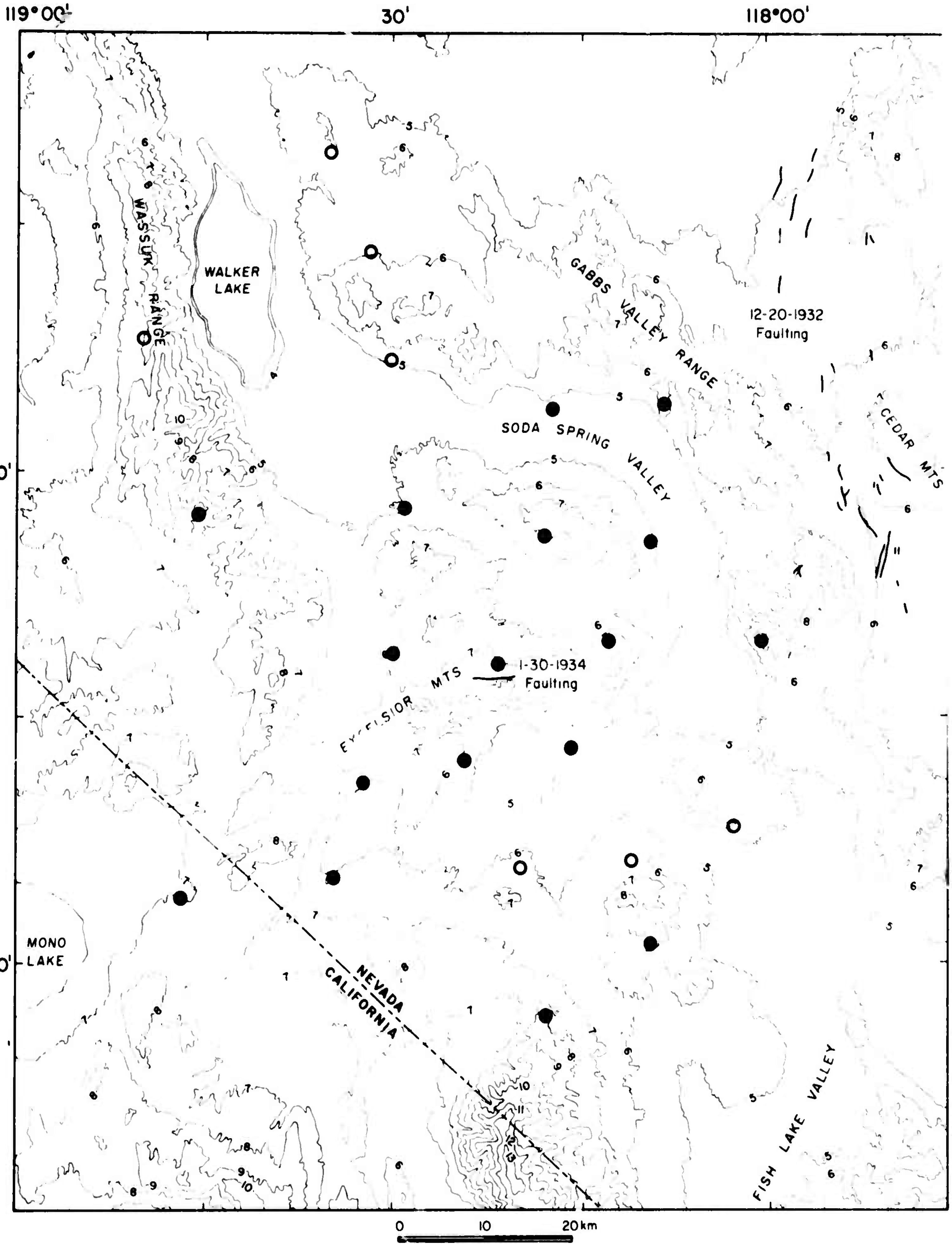

119°00'
30'
118°00'
30'
38°00'
WASSUK RANGE
WALKER LAKE
GABBS VALLEY RANGE
12-20-1932
Faulting
SODA SPRING VALLEY
CEDAR MTS
1-30-1934
Faulting
EXCELSIOR MTS
MONO LAKE
NEVADA
CALIFORNIA
FISH LAKE VALLEY
0
10
20 km

FIGURE 31